MARINE MAMMAL AND SEA TURTLE MONITORING DURING LAMONT-DOHERTY EARTH OBSERVATORY'S MARINE SEISMIC PROGRAM IN THE EASTERN TROPICAL PACIFIC OCEAN OFF CENTRAL AMERICA, NOVEMBER–DECEMBER 2004

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and

National Marine Fisheries Service, Office of Protected Resources
1315 East-West Hwy, Silver Spring, MD 20910-3282

LGL Report TA2822-30

April 2005

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by

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Suggested format for citation:

Holst, M., M.A. Smultea, W.R. Koski, and B. Haley 2005. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific Ocean off Central America, November–December 2004. LGL Rep. TA2822-30. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 125 p.

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

~	approximately
Bf	Beaufort Wind Force
CFR.	(U.S.) Code of Federal Regulations
CIBRA	Centro Interdisciplinare di Bioacustica e Ricerche Ambientali (Univ. of Pavia, Italy)
CITES	Convention on International Trade in Endangered Species
CPA	Closest (Observed) Point of Approach
dB	decibels
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
ESA	(U.S.) Endangered Species Act
ETP	Eastern Tropical Pacific
ETPCA	Eastern Tropical Pacific off Central America
$f(0)$	sighting probability density at zero perpendicular distance from the survey track line; equivalently, 1/(effective strip width)
ft	feet
GI	Generator–Injector
GIS	Geographic Information System
GMT	Greenwich Mean Time
$g(0)$	probability of seeing a group located directly on the survey trackline
GPS	Global Positioning System
h	hours
hp	horsepower
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under MMPA)
in^3	cubic inches
indiv.	individual(s)
ITS	Incidental Take Statement
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometer
km/h	kilometers per hour
kW	kilowatt
L-DEO	Lamont-Doherty Earth Observatory (of Columbia University)
μPa	micro Pascal
m	meter
max.	maximum
MBB	Multi-beam Bathymetric Sonar
min	minutes
MMO	Marine Mammal (and Sea Turtle) Observer
MMPA	(U.S.) Marine Mammal Protection Act
ms	millisecond
n	sample size

n. mi.	nautical miles
NMFS	(U.S.) National Marine Fisheries Service
No.	number
NSB	Northern Sandino Basin
NSF	(U.S.) National Science Foundation
NVD	Night Vision Device
PAM	Passive Acoustic Monitoring
PD	Power down of the GI guns to one operating GI gun
PI	Principal Investigator
RDT	Rotational Directional Transmission (re Multi-beam Sonar)
re	in reference to
rms	root-mean-square
s	seconds
SD	Shut Down of all the GI guns—not associated with mitigation (*cf.* SZ)
SEAMAP	SEAMAP Cetacean Monitoring System
SSB	Southern Sandino Basin
SZ	Shut Down of all the GI guns because of a marine mammal or sea turtle sighting near or within the safety radius (*cf.* SD)
TTS	Temporary Threshold Shift
U.S.C.	U.S. Code
"Useable"	Visual effort or sightings made under the following observation conditions: daylight periods both within the seismic survey area and during transit to and from that area, ***excluding*** periods 90 s to 2 h after guns were turned off (post-seismic), nighttime observations, poor visibility conditions (visibility <3.5 km), and periods with Beaufort Wind Force >5 (>2 for cryptic species). Also excluded were periods when the *Ewing*'s speed was <3.7 km/h (2 kt) or with >60° of severe glare between 90º left and 90º right of the bow.
UT	University of Texas, Institute of Geophysics, Austin, TX

EXECUTIVE SUMMARY

Introduction

This document serves to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) issued to Lamont-Doherty Earth Observatory (L-DEO) by the National Marine Fisheries Service (NMFS) on 19 Nov. 2004. The IHA (Appendix A) authorized non-lethal takes of certain marine mammals incidental to a low-energy marine seismic survey in the Eastern Tropical Pacific Ocean (ETP) off Central America (i.e., the ETPCA project). Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). Cetaceans exposed to airgun sounds with received levels ≥160 dB re 1 µPa (rms) might be sufficiently disturbed to be "taken by harassment". "Taking" would also occur if marine mammals close to the seismic activity experienced a temporary or permanent reduction in their hearing sensitivity, or reacted behaviorally to the airgun sounds in a biologically significant manner.

It is not known whether seismic exploration sounds are strong enough to cause temporary or permanent hearing impairment in any marine mammals or sea turtles that occur close to the seismic source. Nonetheless, to minimize the possibility of any injurious effects (auditory or otherwise), and to document any disturbance effects, NMFS requires that seismic programs conducted under IHAs include monitoring for marine mammals and sea turtles, and provisions to power down or shut down the airguns when marine mammals or turtles are detected within designated safety radii. In this project, a power down was a reduction to one operating GI gun, whereas a shut down involved complete cessation of GI gun operations.

During the ETPCA cruise, there were 12 power downs and shut downs for cetaceans and 87 for sea turtles (Table ES.1). This was a larger number of interruptions of seismic operations than during any of the previous eight L-DEO marine seismic surveys conducted under the provisions of IHAs issued by NMFS (although early IHAs did not require such action for sea turtles). A high proportion of shut downs and power downs were associated with sea turtle sightings because of ***(1)*** the proximity of the cruise to active nesting beaches, primarily in Costa Rica, plus ***(2)*** the use of a precautionary safety criterion for sea turtles (170 dB re 1 µPa rms). These interruptions in seismic data acquisition compromised the continuity of geophysical data collection needed for detailed seismic stratigraphic interpretation and to meet the scientific goals of the ETPCA geophysical project.

Seismic Program Described

The main purpose of the study was to obtain seismic data to investigate stratigraphic development in the presence of tectonic forcing in the Sandino Forearc Basin. The survey encompassed an area between 10º and 13ºN and 86º to 88ºW in the ETP off Central America. Water depths within the study area ranged up to 5000 m. The study was conducted in the Exclusive Economic Zones (EEZ) of several nations, including Costa Rica, Honduras, Nicaragua, and El Salvador. The R/V *Maurice Ewing* departed Puntarenas, Costa Rica, on 21 Nov. 2004 and arrived in the study area later that same day. The *Ewing* conducted seismic operations off the coast of Central America for ~29 days. The vessel departed the study area on 20 Dec. and arrived in Balboa, Panama, on Dec. 22.

This seismic survey used an array of three GI guns with two different configurations: three 45 in^3 GI guns with a total generator volume of 135 in^3, and three 105 in^3 GI guns with a total generator volume of 315 in^3. The GI guns were towed by the *Ewing*. A 1.5-km streamer containing hydrophones was also

TABLE ES.1. Total *Ewing* operations, observer and passive acoustic monitoring (PAM) effort, and marine mammal and sea turtle sightings during the ETPCA seismic survey, 21 Nov. – 22 Dec. 2004.

	Non-Seismic			Seismic			
	Useable[a]	Other	Post Seismic	Useable[a]	Other	Total Useable[a]	Total
Operations in h							
Ewing Nighttime	0	31	3	0	329	0	362
Ewing Daylight	37	4	20	257	65	293	382
***Ewing* Total**	**37**	**34**	**22**	**257**	**394**	**293**	**744**
Observer Nighttime		1	1		186	0	187
Observer Daylight	33	1	20	255	65	288	373
Observer Total	**33**	**2**	**20**	**255**	**251**	**288**	**561**
PAM Nighttime		1	0		308	0	309
PAM Daylight	4	0	18	251	50	255	324
PAM Total	**4**	**1**	**19**	**251**	**358**	**255**	**632**
Operations in km							
Ewing Nighttime	0	525	18	0	2680	0	3223
Ewing Daylight	688	15	165	2134	504	2822	3505
***Ewing* Total**	**688**	**540**	**183**	**2134**	**3184**	**2822**	**6729**
Observer Nighttime		8	4		1537	0	1549
Observer Daylight	610	14	165	2124	504	2734	3416
Observer Total	**610**	**21**	**169**	**2124**	**2041**	**2734**	**4965**
PAM Nighttime		4	4		2521	0	2529
PAM Daylight	**30**	2	152	2087	401	2116	2672
PAM Total	**30**	**7**	**156**	**2087**	**2922**	**2116**	**5200**
No. Cetacean Sightings	26	4	1	42	8	68	81
No. Cetacean Acoustic Detections	4	1	6	77	129	81	217
No. Sea Turtle Sightings	15	0	43	102	11	117	171[b]
No. Power Downs (PD) or Shut Downs (SZ) for Cetaceans[c]	na[d]	na	na	7	5	7	12
No. PD or SZ for Sea Turtles	na	na	na	80	7	80	87
PD or SZ Total	**na**	**na**	**na**	**87**	**12**	**87**	**99**

[a] See Acronyms and Abbreviations for the definition of "useable" effort.

[b] Five groups (five separate individuals) of the 171 groups of sea turtles seen during the cruise were dead. These five dead sea turtles were excluded from the "useable" total. For each of these sightings, the observers concluded that the turtle had been dead for an extended period and had not been injured or killed by the seismic operations then in progress.

[c] Five of the total 12 shut downs and power downs involved two different groups of cetaceans as follows. Two shutdowns and one power down were conducted on separate occasions for the same single pantropical spotted dolphin identified repeatedly over a ~26-h period. In addition, one power down was followed by a shut down for the same humpback group when it subsequently approached within the smaller safety radius around a single GI gun.

[d] na = not applicable.

towed behind the *Ewing* to receive the returning seismic acoustic signals. In addition, a 250-m hydrophone array was towed behind the *Ewing* to conduct passive acoustic monitoring (PAM) for vocalizing cetaceans. A multibeam bathymetric (MBB) sonar and a lower energy 3.5 kHz sub-bottom profiler were operated from the *Ewing* during most of the cruise, including during all seismic operations. To aid in safe vessel navigation, a standard 10.5-kHz depth sounding sonar was used occasionally in very shallow areas where nautical charts were insufficiently detailed; this type of sonar is routinely employed by sea-going vessels to monitor water depths.

Monitoring and Mitigation Description and Methods

A total of five trained marine mammal observers (MMOs) were aboard the *Ewing* throughout the period of operations for visual and acoustic monitoring. The primary purposes of the monitoring and mitigation effort were the following: ***(A)*** Document the occurrence, numbers and behaviors of marine mammals and sea turtles near the seismic source. ***(B)*** Implement a power down or shut down of the GI guns when marine mammals or turtles were sighted near or within the designated safety radii. ***(C)*** Monitor for marine mammals and sea turtles before and during ramp-up periods.

At least one MMO watched for marine mammals and sea turtles at all times while GI guns operated during daylight, just prior to and during all nighttime ramp-up periods, and during nighttime seismic operations adjacent to turtle nesting beaches. During night periods when MMOs were not on active duty, the bridge crew watched for marine mammals and sea turtles near the vessel with the naked eye as part of their normal watch duties, and at least one MMO was on call. Visual observers also conducted watches during daytime periods when the source vessel was underway but the GI guns were not firing.

The visual MMOs scanned the surface of the water around the vessel for marine mammals and sea turtles. The MMOs used 7 × 50 reticle binoculars, 25 × 150 “Big-eye” binoculars, the naked eye, and (at night) night vision devices (NVDs). When marine mammals or turtles were sighted, the distance from the nearest GI gun in the array to the nearest member of the marine mammal or sea turtle group was estimated using reticles on one ocular lens of the binoculars. When a marine mammal or turtle was detected within or approaching the safety radius, the visual MMO contacted the GI gun operators to shut down all GI guns, or all but one GI gun; the latter is a “power down”.

In addition to visual monitoring, MMOs conducted 24-h PAM. The primary purpose of the acoustic monitoring was to aid visual observers in detecting vocalizing marine mammals, particularly during periods with poor observation conditions, including high sea states, fog, or darkness, when visual monitoring is nearly ineffective. The acoustic MMO listened with headphones or speakers to sounds received from the hydrophone array and simultaneously monitored a real-time spectrogram display. When a calling cetacean was detected, the acoustic MMO phoned the visual MMOs and communicated the presence and (when determinable) bearing and estimated distance of the animal.

Mitigation procedures, as required by the IHA, included the following: ***(1)*** Changes in vessel heading and speed to avoid marine mammals ahead of the vessel if possible. ***(2)*** Ramp ups whenever the GI guns were started after periods without GI gun operations or after prolonged operations with one GI gun. ***(3)*** Immediate power downs or shut downs of the GI guns whenever marine mammals or sea turtles were detected within or about to enter the safety radius applicable to the seismic source in use and the water depth at the time.

The safety radii varied during the survey depending on the GI-gun configuration in use, water depth, and type of marine animal (sea turtle, cetacean, or pinniped):

- The safety radii for ***cetaceans*** were based on the distances within which the received levels of GI gun sounds were expected to diminish to 180 dB re 1 µPa (rms) in different water depths. For the 315 in^3 array, the 180 dB safety radii for cetaceans were 574 m in shallow water (<100 m depth), 123 m in intermediate water depths (100–1000 m), and 82 m in deep water (>1000 m). For the 135 in^3 array, the respective 180 dB safety radii were 433 m, 93 m, and 62 m.
- The safety radii for ***sea turtles*** were based on the distances within which the received level of GI gun sounds diminish to 170 dB—a precautionary non-standard criterion applied by NMFS in this project given the importance of the area to nesting sea turtles. For turtles, the more precautionary radii applicable to the largest (315 in^3) array were applied whenever 3 or 2 GI guns were used. These safety radii were, respectively, 1325 m, 398 m, and 265 m in shallow, intermediate-depth, and deep water.
- For ***pinnipeds***, the safety radii were based on distances within which the received levels of GI gun sounds diminish to 190 dB. As for turtles, the safety radii for pinnipeds were those applicable to the largest (315 in^3) array whenever 3 or 2 GI guns were used. However, no pinnipeds were observed during the cruise.
- When 1 GI gun was operating, for example during a power down, a separate set of smaller safety radii appropriate to the largest (105 in^3) single GI gun were applied.

Monitoring Results

The study area for the purposes of marine mammal and sea turtle data analyses was the actual seismic survey area plus the transits from Costa Rica and to Panama. These areas are characterized by similar water depths within the Central American Coastal Province of the Pacific Coastal Biome. This biome extends from the tip of Baja California to Equador.

The *Ewing* traveled a total of 6729 km during the entire trip (Table ES.1; Fig. 1.1). The GI guns operated night and day along 79% of the total ship track. Nearly all (96%) seismic operations were conducted with the three-GI-gun array; the remaining operations were conducted during ramp ups (1%) or with one (2%) or two (1%) GI guns during power downs and turns between seismic lines. The actual number of kilometers traveled during seismic periods was lower than anticipated in the ETPCA IHA Application and EA (5318 vs. 6048 km, respectively).

In total, 4965 km of visual observations and 5200 km of PAM were conducted (Table ES.1). *Ewing* MMOs were on visual watch for 78% of all GI gun operations, and PAM occurred during 94% of all seismic periods. Most (69%) visual effort occurred during daylight, with the remaining 31% conducted at night. Nighttime visual watches were required only when there were nighttime ramp ups or when near sea turtle nesting areas. PAM effort occurred nearly equally during day and night (51 vs. 49%).

Analyses of cetacean and sea turtle behavior and density data were limited to sightings and survey effort during "useable" survey conditions, which occurred during 55% of the total visual effort (Table ES.1). "Useable" effort included daylight effort both within the seismic survey area and during transit to and from that area. It excluded periods 90 s to 2 h after guns were turned off (post-seismic), nighttime observations, poor visibility conditions (visibility <3.5 km), and periods with Beaufort Wind Force >5 (>2 for cryptic species). Also excluded were periods when the *Ewing*'s speed was <3.7 km/h (2 kt) or with >60° of severe glare between 90º left and right of the bow. About ~41% of all PAM effort was concurrent with useable daylight visual effort.

Ramp ups were conducted when the GI guns were turned on for the first time or after the gun(s) had been off for >4 min. Ramp ups (from 1 GI gun to 3 GI guns) were also conducted after prolonged periods with 1 GI gun operating. For example, a ramp up occurred after a power down to 1 GI gun for a cetacean or sea turtle sighting within or near the safety radii, or at night if at least 1 GI gun had been operating continuously since daylight. Ramp ups of the GI guns occurred on 67 occasions, including 8 night-time ramp ups from 1 to 3 GI guns. As required by the IHA, no start ups from a full shut down were performed at night. In addition to the 67 ramp-ups, there were 31 additional start-ups of a single GI gun. MMOs were on visual watch during all start ups and ramp ups.

Cetaceans

A total of 34 cetacean species are known to or may occur in the ETP. Pinnipeds were not expected in this region and none were observed during the cruise. Within the ETPCA study area, an estimated 2091 individual cetaceans were seen in 81 groups and 217 acoustic detections were made (Table ES.1). At least nine species of cetaceans were identified. No injured cetaceans potentially associated with the operations were sighted at any time during the cruise.

The pantropical spotted dolphin (n = 13 sightings) and humpback whale (n = 11) were the most commonly identified cetacean species, followed by the bottlenose dolphin (n = 8 sightings). On an individual basis, many more spinner dolphins (n = 1350 individuals) were identified than any other cetacean species. Humpback whales and a single minke whale were the only baleen whales identified to species during the cruise. Minke whales are considered rare in the region. A small concentration of humpbacks (12 individuals in 8 groups) was seen in the Gulf of Fonseca near the Honduras border on 9 Dec., including two singing whales. To our knowledge, concentrations of humpbacks, particularly singing humpbacks, have not previously been reported in this specific area. A humpback mother-calf pair was seen off northern Costa Rica on 25 Nov. The date of this mother-calf sighting during the ETPCA cruise suggests that this pair may have been from the southern hemisphere population of humpbacks, which would be considered rare for this far north.

A total of 217 acoustic detections were made during the ETPCA cruise (Table ES.1). Most (194 detections) were unidentified dolphins. The remaining 23 detections could be matched with a visual sighting and were identified as pantropical spotted, spinner, and bottlenose dolphins, humpback whales, short-finned pilot whales, and possible false killer whales. Acoustic detection rates were higher than visual detection rates, which is typical for joint visual/acoustic surveys. Acoustic detection rates were twice as high at night as during the day, whereas visual sightings at night were rare.

The sighting rates during "useable" non-seismic periods were higher than during seismic periods. However, useable effort was over three times higher during seismic compared to non-seismic conditions, and non-seismic effort was small. Because PAM effort in the absence of seismic operations was so limited during this cruise, it was not possible to determine whether acoustic detection rates were notably different during seismic vs. non-seismic periods. Regardless, the ETPCA PAM results (and some previous studies) indicate that at least some cetaceans call in the presence of airgun and GI gun pulses.

For the first time during an L-DEO seismic survey, two groups of cetaceans were initially detected at night with the night vision device goggles (NVDs). The only other *Ewing* seismic cruise in which nighttime visual detections were made by MMOs was the SE Alaska cruise, when a group of Dall's porpoises were heard splashing and then seen via the naked eye and NVDs near the bow. A total of six nighttime visual detections were made during the ETPCA cruise, two of which were initially detected with the NVDs. All six groups were seen near the *Ewing*'s bow while 3 GI guns with total volume 135 in^3 were operating in Beaufort Wind Force 1–4. Power downs were implemented for four of these six groups because they were within (n = 1) or near (n = 3) but still outside the safety radii for the 3 GI guns operating in the applicable water depths. Power downs were not done for the remaining two groups because they were outside the safety radius and were last seen moving away from the vessel/array.

In general, behavior and movement of cetaceans during both seismic and. non-seismic periods were variable, and sample sizes were small during non-seismic periods. Delphinids and whales tended to be sighted farther from the observation vessel during seismic than during non-seismic periods; however, the sample sizes were small with large standard deviations. Bowriding delphinids were seen on nine occasions: eight during seismic periods and once during a non-seismic period. While bowriding at or near the surface, cetaceans would receive lower sound pressure levels relative to those at depth because of the pressure release effect at the surface.

A single pantropical spotted dolphin followed, circled, and sometimes vocalized on and off near the *Ewing* over a period of ~26 h during both seismic and non-seismic periods. The observations suggest that this individual may have become habituated to the GI gun sounds. This animal did not appear to be displaced by the GI gun sounds, but may have been attracted by the ship or the GI gun pulses.

Sea Turtles

A total of five species of sea turtles are known to or may occur in the ETP. During the ETPCA study, ~179 sea turtles were seen in 171 groups (Table ES.1). Three species were identified: 84 individual olive ridleys, 1 leatherback, and 2 possible green sea turtles. Five of the observed turtles were dead adults, including one possible green sea turtle and four unidentified sea turtles. For each of these sightings, the observers concluded that the turtle had been dead for an extended period and had not been injured or killed by the seismic operations then in progress. Thus, seismic activities were not suspended for any of the dead turtle sightings. NMFS was notified of several of these dead turtles on 27 Nov. 2004.

The highest density of sea turtle sightings occurred in the Northern Sandino Basin area and the lowest density occurred in the area of the Southern Sandino Basin. Because of the proximity of the southern part of the project area to turtle nesting sites, high densities were expected there. However, the high densities witnessed in the Northern Sandino Basin relative to the Nicoya Peninsula and Southern Sandino Basin were unexpected, because there are no known nesting beaches near the Northern Sandino Basin area.

Most (66%) of the 171 turtle groups were seen during seismic periods (113 groups); 15 groups were seen during non-seismic periods and 43 groups were seen during post-seismic periods (Table ES.1). Of the 171 turtle groups seen, 68% (117 groups) were sighted during "useable" survey conditions, and most (87%) of those were observed during seismic operations (Table ES. 1). Sightings under non-seismic conditions (n = 15) were too infrequent for detailed interpretation of potential effects of seismic operations. "No movement" and logging were the most commonly observed sea turtle movement and behavior, respectively, during both seismic and non-seismic conditions. Sea turtle groups tended to be sighted farther from the GI guns during seismic than during non-seismic conditions; mean closest observed points of approach were 320 m vs. 127 m, respectively (n = 102 vs. 15 groups).

A total of 71 shut downs and 16 power downs were implemented during the cruise because of sea turtles (Table ES.1). All shut downs occurred when a turtle was first sighted within the 170 dB sound radii; there were no cases when a full shut down had been preceded by an initial power down. However, all of the observed turtles were seen at the water surface where the sound levels are much lower than those that would occur at the same radius deeper in the water. For that reason, along with the use of 170 dB radii appropriate to the larger GI guns even when the smaller guns were in use, many of the groups first sighted within the safety radii would not have been receiving ≥170 dB when seen. Ramp ups were interrupted four times because of the presence of sea turtles, and ramp ups had to be postponed on numerous occasions due to sea turtles within the safety radius.

The implementation of the 170 dB sound radius as a safety criterion for sea turtles was a precautionary and somewhat presumptive measure given the limited available data regarding the effects of airgun sound on sea turtles. Based on distances at the closest observed point of approach to sea turtle groups, seismic operations may have displaced some sea turtles from the immediate vicinity of the approaching vessel. However, the non-seismic sample size was small and limits data interpretation.

All turtle sightings were of relatively large individuals. However, large numbers of hatchlings were presumably also present but not observed, based on the proximity of active nesting beaches. The smaller turtles that were presumed to be present were not sighted, and thus did not trigger power downs or shut downs.

Number of Marine Mammals Present and Potentially Affected

It is difficult to obtain meaningful estimates of "take by harassment" for several reasons. These include problems in estimating the number of mammals present in the area, difficulty in determining appropriate take criteria, variability in sound propagation, and depth-related variability in sounds received by cetaceans. Also, in this project, use of a variety of airgun configurations at different times contributed to variability in received levels at any given distance from the source. Any large cetaceans or beaked whales that might have been exposed to received sound levels ≥160 dB re 1 μPa (rms), and delphinids exposed to received levels of ≥170 dB re 1μPa, were assumed to have been potentially disturbed. The numbers of cetaceans observed or estimated to be within various exposure zones around the seismic source (160, 170, 180, and 190 dB radii) provide estimates of the numbers potentially affected by seismic sounds.

During this project, the "safety radii" called for by NMFS for cetaceans were the best estimates of the actual 180-dB radii for the 3-GI-gun configurations actually used. However, during operations with one or two GI guns, the radii used in the field were farther from the GI gun(s) than the actual estimated 180 dB radii. The GI guns were shut down four times and powered down eight times because of the presence of nine different cetacean groups within or near the designated, depth-appropriate safety zones (Table ES.1). One of the power downs was followed by a shut down when the same humpback group subsequently came within the smaller safety radius around the single GI gun. Two of these shutdowns and a power down were implemented for the same lone pantropical spotted dolphin present for a 26-h period. Eight power downs or shut downs were attributable to cetaceans that were first observed in the safety zone, and four were precautionary for cetaceans sighted near but outside the safety zone for the given water depth and array configuration. In total, three different individual cetaceans (one pantropical spotted dolphin and two humpback whales) were estimated to have been exposed to GI gun sounds ≥180 dB before mitigation measures could be implemented. However, only one or a few shots might have been fired while these cetaceans were within this safety zone.

Based only on direct observations, a total of 32 cetacean groups involving 248 individuals were seen within the ≥160 dB radii around the operating GI guns. These include 25 delphinid groups and 7 other cetacean groups, after discounting resightings. However, the ≥160 dB criterion of potential disturbance is considered realistic only for the non-delphinid groups (n = 7). These seven different cetacean groups involved two unidentified baleen whales and eight different humpback whales. One of these groups included a mother-calf pair. The 170 dB radius is considered a more realistic disturbance criterion for delphinids. A total of 11 different delphinid groups involving 88 different individuals are considered to have been exposed to GI gun sounds ≥170 dB, and thus potentially disturbed by seismic sounds based on the "direct observation" method (this excludes two resightings of the same pantropical spotted dolphin).

Minimum and maximum numbers of cetaceans exposed to ≥160 and ≥170 dB re 1 μPa (rms) were also estimated based on densities of cetaceans derived by line-transect procedures during seismic and non-seismic periods. These estimates allow for animals not seen by MMOs. An estimated 1632 individual cetaceans might have been in the areas about to be exposed to GI gun sounds with received levels ≥160 dB re 1 μPa (rms), based on observations during non-seismic periods. Among the estimated 1632 individual cetaceans potentially affected were ~1626 delphinids and 7 other cetaceans. For delphinids, the number of those species within the smaller area exposed to ≥170 dB would have been ~601. Thus, based on this approach, a total of ~608 cetaceans (i.e., 7 + 601) might have been exposed to sound levels that could have disturbed them. Except for humpback whales and false killer whales, all estimates based on actual density data during both seismic and non-seismic periods are lower than the "harassment takes" estimated prior to the survey. The total estimated number of individual cetaceans in areas exposed to ≥160 dB is ~7% of the maximum number estimated in the IHA application.

Available evidence suggests that cetaceans did not show strong avoidance of the seismic vessel, except possibly at very close range, and that they did not change their behavior in ways that made them dramatically less (or more) conspicuous to observers. This is not surprising, given the small sound sources used in this project as compared with many seismic surveys.

In any event, the estimated number of cetaceans potentially affected by L-DEO's ETPCA survey was much lower than authorized by NMFS. Given this, and the mitigation measures that were applied, the effects were very likely localized and transient, with no significant impact on either individual cetaceans or their populations.

Results of L-DEO's ETPCA marine mammal and sea turtle monitoring program provide concentrated survey effort near the little-studied Pacific coasts of Honduras, Nicaragua, and northern Costa Rica during Nov. and Dec. The sighting database includes records of some species and age classes rarely reported from this region of the ETP. The results also provide a comparison of the relative effectiveness and complementary nature of visual vs. acoustic surveys.

1. INTRODUCTION

Lamont-Doherty Earth Observatory (L-DEO) supported a marine seismic study in the Eastern Tropical Pacific Ocean (ETP) off Central America from 21 Nov. to 22 Dec. 2004 (Fig. 1.1). The project was conducted aboard the R/V *Maurice Ewing*, which is owned by the National Science Foundation (NSF) and operated by L-DEO. The study used an array of 3 GI or "generator-injector" guns (a type of airgun) as the energy source, and was under the direction of Principal Investigators (PIs) Drs. Kirk McIntosh and Craig Fulthorpe of the University of Texas (UT) Institute of Geophysics.

The purpose of the seismic survey was to investigate stratigraphic development in the presence of tectonic forcing in the Sandino Forearc Basin west of Nicaragua and Costa Rica. Because of the marked along-strike variations in subsidence/uplift histories within the Sandino Basin, and the inability to provide whole-basin coverage during a cruise of reasonable length, data were collected in several subareas: two primary grids in the Sandino Basin (Grids 1 and 2); a third, smaller grid off Nicoya Peninsula (Grid 3); and in a series of lines in the Gulf of Fonseca (Grid 4):

- Grid 1 (northern Sandino Basin) was the ideal environment to investigate both the eustatic and tectonic components of sequence formation.
- The focus of Grid 2 (southern Sandino Basin) was to determine the timing of the uplift, the apparent recent subsidence, and also, using the connecting profiles to Grid 1, the regional, presumed eustatic, sequence boundaries.
- Grid 3 was selected to bear on the controversy between interpretations of small-scale underplating accretion versus massive subduction erosion.
- Grid 4 was of interest because the Gulf of Fonseca may represent a primary sediment pathway for sediment supply to the Sandino Basin, and the seismic data will provide an opportunity to link source and sink. Those profiles will also provide a link to onshore structural work, as they cross the tectonic boundary between the volcanic arc and the Nicaraguan depression. The nature of that boundary is unconstrained at present.

Marine seismic surveys emit strong sounds into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b), and have the potential to affect marine mammals, given the known auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995). The effects could consist of behavioral or distributional changes, and perhaps (for animals close to the sound source) temporary or permanent reduction in hearing sensitivity. Either behavioral/distributional effects or (if they occur) auditory effects could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species (ESA) Act, at least if the effects are considered to be biologically significant.

Numerous species of cetaceans inhabit the ETP off Central America, including various dolphins, toothed whales, and baleen whales. Several of these species are listed as endangered under the U.S. ESA, including humpback, sei, fin, blue, and sperm whales. Other species of special concern in the area include the endangered leatherback and hawksbill sea turtles, and the threatened loggerhead, green, and olive ridley sea turtles. Pinnipeds do not occur regularly in the ETP off Central America and were not seen during the study.

On 28 June 2004, L-DEO requested that the National Marine Fisheries Service (NMFS) issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to the airgun operations planned in the ETP (LGL Ltd. 2004a). The IHA was requested pursuant to

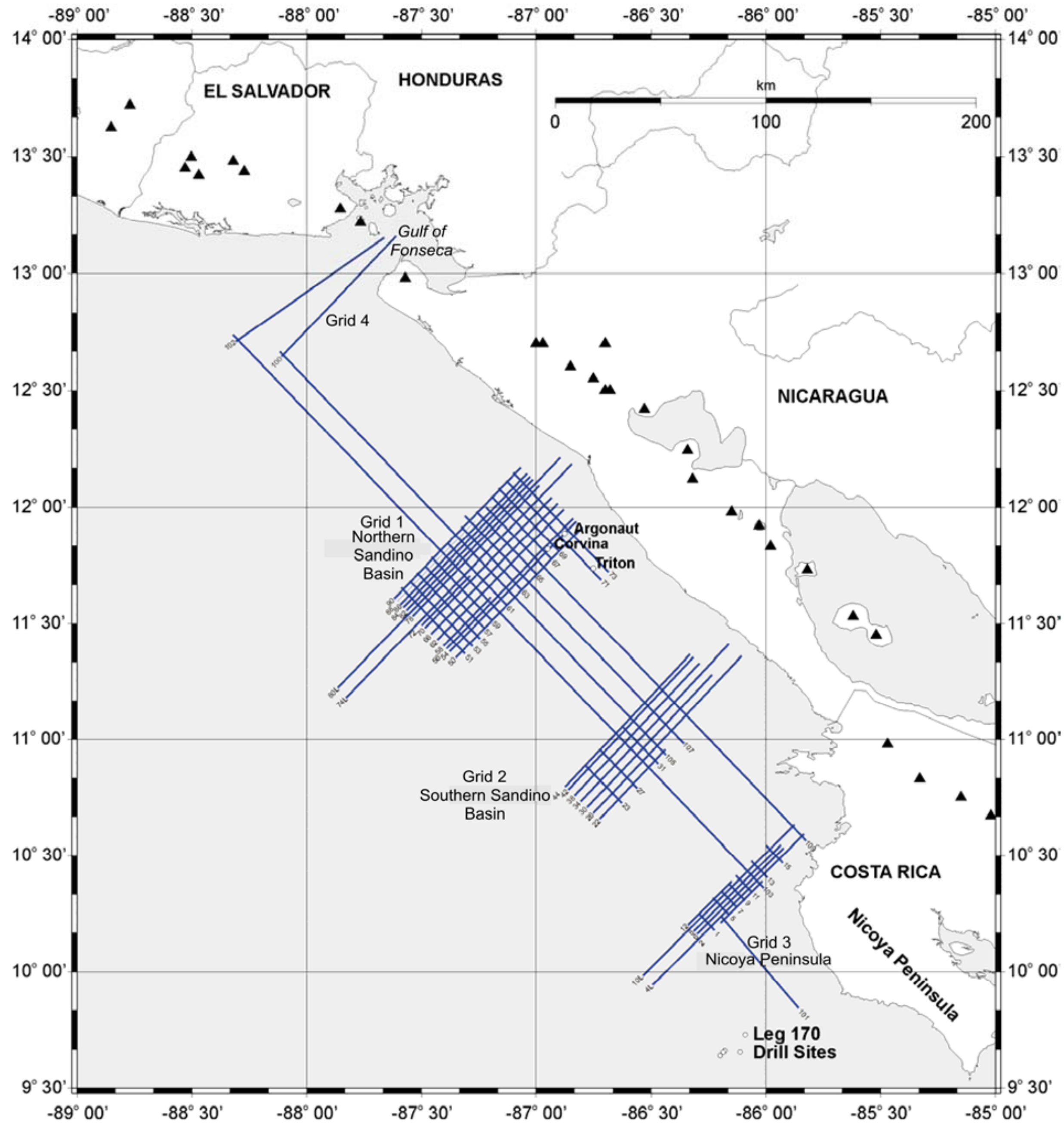

FIGURE 1.1. The study area, *Ewing* ship tracks, and locations of the four seismic survey grids and survey lines during the ETPCA seismic cruise conducted in the Sandino Forearc Basin in the Eastern Tropical Pacific Ocean off Central America, 21 Nov.–22 Dec. Data gaps resulting from the 99 shut down and power downs of the GI guns for marine mammal and sea turtle sightings are not shown. Commercial exploration wells Argonaut, Corvina, and Triton and ODP Leg 170 drill sites are indicated. The triangles represent locations of volcanic arcs.

Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was also written to evaluate the potential impacts of the marine seismic survey in the ETP (LGL Ltd. 2004b). That EA was adopted by NSF, the federal agency sponsoring this seismic survey. The IHA was issued by NMFS on 19 Nov. 2004 (NMFS 2004b; Appendix A).

That IHA authorized "potential take by harassment" of marine mammals during the ETPCA seismic cruise described in this report. The IHA provided for seismic operations using two different configurations of a 3-GI-gun array (total generator discharge volumes of 135 or 315 in^3) as the energy source. The first and last days of seismic operations occurred on 22 Nov. and 20 Dec. 2004. The ship left Puntarenas, Costa Rica, on 21 Nov. and arrived in the study area later that same day. The vessel left the study area on 20 Dec. and arrived in Balboa, Panama, on 22 Dec. The airguns did not operate during transits at the start and end of the cruise.

This document serves to meet reporting requirements specified in the IHA. The primary purposes of this report are to describe the seismic survey in the ETP, to describe and present the results of the associated marine mammal and sea turtle monitoring and mitigation program, and to estimate the numbers of marine mammals potentially affected by the project.

Incidental Harassment Authorization

IHAs issued to seismic operators include provisions to minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries. During this project, sounds were generated by the airguns used during the seismic study, a multi-beam bathymetric (MBB) sonar, a sub-bottom profiler, and by general vessel operations. No serious injuries or deaths of marine mammals (or sea turtles) were anticipated from the ETPCA seismic survey, given the nature of the operations and the mitigation measures that were implemented, and no injuries or deaths were attributed to the seismic operations. Nonetheless, the seismic survey operations described in Chapter 2 had the potential to "take" marine mammals by harassment. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the MMPA. Appendix B provides further background on the issuance of IHAs relative to seismic operations and "take".

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB re 1 μPa (rms)[1] for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. Those safety radii are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these mammals or impair their hearing abilities, but that higher received levels *might* have some such effects. The mitigation measures required by IHAs are, in large part, designed to avoid or minimize numbers of marine mammals exposed to sound levels exceeding the 180 or 190 dB (rms) levels. In addition, for this project, NMFS also specified a special safety (shut-down) criterion of 170 dB (rms) for sea turtles.

Disturbance to marine mammals could occur at distances beyond the safety (=shut down) radii if the mammals were exposed to moderately strong pulsed sounds generated by the airgun array or perhaps

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[1] "rms" means "root mean square", and represents a form of average across the duration of the sound pulse as received by the animal. Received levels of airgun pulses measured on an "rms" basis are generally 10–12 dB lower than those measured on the "zero-to-peak" basis, and 16–18 dB lower than those measured on a "peak-to-peak" basis (Greene 1997; McCauley et al. 1998, 2000). The latter two measures are the ones commonly used by geophysicists. Unless otherwise noted, all airgun pulse levels quoted in this report are rms levels.

sonar (Richardson et al. 1995). NMFS assumes that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 µPa (rms) are likely to be disturbed appreciably. That assumption is based mainly on data concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). Dolphins and pinnipeds are generally less responsive (e.g., Stone 2003; Gordon et al. 2004), and 170 dB (rms) may be a more appropriate criterion of behavioral disturbance for those groups (LGL Ltd. 2004a,b). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time, its distance from the sound source, and the received level of the sound and the associated water depth. Some individuals respond behaviorally at received levels somewhat below the nominal 160 or 170 dB (rms) criteria, but others tolerate levels somewhat above 160 or 170 dB without reacting in any substantial manner.

A notice regarding the proposed issuance of an IHA for the ETPCA project was published by NMFS in the *Federal Register* on 30 Sept. 2004, and public comments were invited (NMFS 2004a). On 19 Nov. 2004, L-DEO received the IHA that had been requested for the ETPCA project. On 13 Dec. 2004 NMFS published a second notice in the *Federal Register* to announce the issuance of the IHA. That notice addressed the one comment received during the 30-day public comment period (NMFS 2004b). A copy of the issued IHA is included in this report as Appendix A.

The IHA was granted to L-DEO on the assumptions that

- the numbers of marine mammals potentially harassed (as defined by NMFS criteria) during seismic operations would be "small",
- the long-term effects of such harassment on marine mammal populations would be negligible,
- no marine mammals would be seriously injured or killed, and
- the agreed upon monitoring and mitigation measures would be implemented.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in L-DEO's IHA Application (LGL Ltd. 2004a) and in the IHA issued by NMFS to L-DEO (Appendix A). Additional explanatory material about the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2004a,b). Although the IHA deals primarily with marine mammals, extra mitigation and monitoring requirements for sea turtles were specified in the Incidental Take Statement (ITS) issued by NMFS in conjunction with the IHA (see Appendix A).

The main purpose of the mitigation program was to avoid or minimize potential effects of L-DEO's seismic survey on marine mammals and sea turtles. This required that L-DEO detect marine mammals and sea turtles within or about to enter the safety radius, and in such cases initiate an immediate power down (or shut down if necessary) of the airguns. A power down involves reducing the source level of the operating airguns, generally by ceasing the operation of all but one airgun. A shut down involves ceasing the operation of all airguns. An additional mitigation objective was to detect marine mammals or sea turtles within or near the safety radii prior to starting the airguns, or during ramp up toward full power; in these cases, the start of airguns was to be delayed or ramp up discontinued until the safety radius was free of marine mammals or sea turtles (see Appendix A and Chapter 3).

The primary objectives of the monitoring program were as follows:

1. Provide real-time sighting data needed to implement the mitigation requirements.

2. Use real-time passive acoustic monitoring (PAM) to monitor for vocalizing cetaceans and to notify visual observers of nearby cetaceans.
3. Estimate the numbers of marine mammals potentially exposed to strong seismic pulses.
4. Determine the reactions (if any) of potentially exposed marine mammals and sea turtles.

Specific mitigation and monitoring objectives as identified in the IHA and ITS are shown in Appendix A. Mitigation and monitoring measures implemented during the ETPCA cruise are described in Chapter 3.

Report Organization

The primary purpose of this 90-day Report is to describe the 2004 seismic study that was conducted in the ETP, including the associated monitoring and mitigation program, and to present results as required by the IHA (see Appendix A). This report includes five chapters:

1. Background and introduction (this chapter);
2. Description of L-DEO's 2004 seismic study in the ETPCA;
3. Description of the marine mammal and sea turtle monitoring and mitigation requirements and methods, including a description of the safety radii used during the seismic study;
4. Results of the marine mammal monitoring program, and estimated numbers of marine mammals potentially "taken by harassment" during this program; and
5. Results of the sea turtle monitoring program.

Those chapters are followed by Acknowledgements and Literature Cited sections.

In addition, there are nine Appendices. Details of procedures that are more-or-less consistent across L-DEO's recent seismic surveys are provided in some of the Appendices and are only summarized in the main body of this report. The Appendices include

A. a copy of the IHA and ITS issued to L-DEO for this study;

B. background on development and implementation of safety radii;

C. characteristics of the R/V *Maurice Ewing*, its GI guns, and its sonars;

D. a detailed description of visual and acoustic monitoring and data analysis methods;

E. conservation status and densities of marine mammals in the project region;

F. summaries of visual and acoustic monitoring effort and sightings during this cruise;

G. detailed descriptions of the cetaceans for which power downs or shut downs were conducted;

H. additional supporting details concerning estimated numbers of marine mammals present and potentially exposed to various seismic sound levels;

I. additional summaries of sea turtle data.

2. ETPCA SEISMIC SURVEY DESCRIBED

The *Ewing* towed the array of 3 GI guns (energy source) and a 1.5 km hydrophone streamer during this seismic study. The streamer was used to receive the returning acoustic signals (Fig. 2.1). In addition, a 300-m SEAMAP Cetacean Monitoring System (SEAMAP) consisting of a four-channel hydrophone array was towed behind the vessel to detect calling cetaceans via passive acoustic monitoring (PAM) methods (see Chapter 3).

Procedures used to obtain seismic data during the ETPCA study were similar to those used during previous seismic surveys by L-DEO, e.g., off the coast of Newfoundland in the North Atlantic (Holbrook et al. 2003). The ETPCA study used conventional seismic reflection techniques to characterize the earth's crust, along with sonars to map the bathymetry and sub-bottom conditions.

The following sections briefly describe the ETPCA seismic survey, the equipment used for the study, and its mode of operation, insofar as necessary to satisfy the reporting requirements of the IHA and ITS (Appendix A). More detailed information on the *Ewing* and the equipment is provided in Appendix C.

Operating Areas, Dates, and Navigation

The ETPCA seismic survey encompassed parts of the area between 10º and 13ºN and between 86º and 88ºW in the ETP off the west coast of Central America (Fig. 1.1). Water depths within the study area ranged from ~20 to 5000 m. The study was conducted in the Exclusive Economic Zones (EEZ) of several nations, including Costa Rica, Honduras, Nicaragua, and El Salvador. The *Ewing* departed Puntarenas, Costa Rica, on 21 Nov. 2004 and arrived in the study area later that evening. The *Ewing* conducted seismic operations off the coast of Central America for ~29 days, commencing on 22 Nov. and ending airgun operations on 20 Dec. The vessel departed the study area on 20 Dec. and arrived in Balboa, Panama, on 22 Dec. A chronology of the study is presented in Table 2.1. A summary of the total distances traveled by the *Ewing* during the ETPCA study, distinguishing periods with and without seismic operations, is presented in Table ES.1.

No seismic survey time was lost because of poor weather, and relatively little survey time was lost because of equipment malfunctions or other technical difficulties. However, a total of ~32 h of lost seismic survey time was incurred because of shut downs and power downs for cetaceans (n = 12) and sea turtles (n = 87) sighted in or near the safety radii for the various GI gun configurations (Fulthorpe and McIntosh 2005). Subsequent ramp ups of the GI guns occurred on 67 occasions, with an additional 31 start-ups of a single GI gun. The aforementioned mitigation involved a larger number of interruptions of seismic operations than during any of the previous eight L-DEO marine seismic surveys conducted under the provisions of IHAs issued by NMFS (although early IHAs did not require such action for sea turtles). A high proportion of shut downs and power downs were associated with sea turtle sightings because of ***(1)*** the proximity of the cruise to active nesting beaches, primarily in Costa Rica, plus ***(2)*** the use of a precautionary safety radius for sea turtles (170 dB re 1 μPa rms). The shut downs and power downs for sea turtles had more effect on seismic data acquisition than did those for cetaceans. Although shut downs and power downs for sea turtles were shorter in duration, they were far more numerous. Interruptions in seismic data acquisition due to these shut downs and power downs resulted in fragmentation of the geophysical data, which disrupted the continuity that is critical for seismic stratigraphic interpretation (Fulthorpe and McIntosh 2005).

Throughout the study, position, speed, and activities of the *Ewing* were logged digitally every minute. In addition, the position of the *Ewing,* water depth, and information on the airgun array were

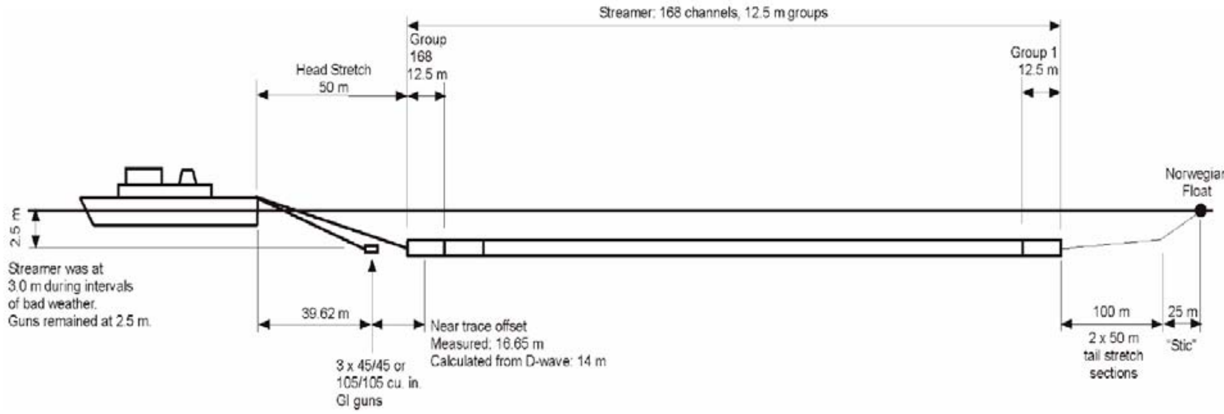

FIGURE 2.1. The towing geometry of the GI gun sources and the 1.5 km hydrophone streamer used to collect the geophysical science data during the ETPCA seismic survey during Nov.–Dec. 2004

TABLE 2.1. Chronology in Greenwich Mean Time (GMT) of events during the Nov.–Dec. 2004 seismic study in the ETPCA off Central America.

Date in 2004	Time	Event Description
21 Nov.	15:00	*Ewing* departed Puntarenas, Costa Rica; MMO transit effort began
21 Nov.	23:49	*Ewing* arrived in seismic study area at dusk; MMO visual transit effort ended due to darkness
22 Nov.	00:45	*Ewing* began deploying SEAMAP hydrophone array, streamer, and airgun array
22 Nov.	00:32	Nighttime visual effort began in seismic study area
22 Nov.	01:04	Started PAM
22 Nov.	01:29	First test shots fired using 1 GI gun
22 Nov.	04:24	GI-guns ramped up for start of survey in Grid 3 (Nicoya Penin.)
27 Nov.	00:12	Started survey in Grid 1 (Northern Sandino Basin)
9 Dec.	06:33	Started survey in Grid 4 (Gulf of Fonseca)
11 Dec.	17:08	Started survey in Grid 2 (Southern Sandino Basin)
20 Dec.	00:01	Ended visual MMO effort within seismic study area at dusk
20 Dec.	03:54	Ended seismic survey; last shot fired; PAM effort ended; *Ewing* left study area
20 Dec.	11:37	MMO transit visual effort began
21 Dec.	21:43	MMO visual transit effort ended; *Ewing* arrived near Balboa, Panama
22 Dec.	15:00	*Ewing* docked in Balboa, Panama

logged for every airgun shot while the *Ewing* was on a seismic line and collecting geophysical data. The geophysics crew kept a written log of events, as did the marine mammal and turtle observers (MMOs) while on duty. The MMOs also recorded the number and volume of airguns that were firing when the *Ewing* was offline (e.g., turning from one line to the next) or was online but not recording data (e.g., during airgun or computer problems).

Airgun Array Characteristics

The 3-GI-gun array and the hydrophone streamer were towed by the *Ewing* along predetermined survey lines in the four different survey grids described in Chapter 1 (Fig. 1.1). Each GI airgun consisted of two chambers, a generator and an injector. It is the generator that is principally responsible for the sound pulse, and references in this report to the volume of the airguns refer to the generator volume. Two different configurations of the 3-GI-gun array were used during this study: ***(A)*** three 105 in^3 GI guns with a total generator volume of 315 in^3, and ***(B)*** three 45 in^3 GI guns with a total generator volume of 135 in^3. Compressed air supplied by compressors aboard the source vessel powered the airgun array. Seismic pulses were emitted at intervals of ~5 s while the *Ewing* traveled at ~7–9 km/h (4–5 kt). At this speed, the 5-s spacing corresponded to a shot interval of ~12.5 m. During operations, the airguns were suspended in the water from air-filled floats and were oriented horizontally, 2.5 m below the water surface and 7.8 m apart (see Appendix C). The characteristics of the 3-GI-gun array used during the study are summarized in Table 2.2.

The nominal source level of the 315 in^3 3-GI-gun array is shown in Table 2.2. The source level would be slightly lower for the 105 in^3 3-GI-gun array. The source levels are as conventionally defined by geophysicists, in zero-to-peak or peak-to-peak terms, and represent the nominal source level for downward propagation of low-frequency energy. Nominal source levels would be somewhat higher if the small amount of energy at higher frequencies were considered. Because the actual source is a distributed sound source (three airguns) rather than a single point source, the highest sound level measurable at any location in the water will be less than the nominal source level (Caldwell and Dragoset 2000). Also, because of the directional nature of the sound from the airgun array, the effective source level for sound propagating in some near-horizontal directions will be lower. The source level on the "root mean square" basis used elsewhere in this report would be lower, but source levels of airguns are not normally determined on an rms basis by airgun manufacturers or geophysicists.

Ewing ***Line Changes***

When the *Ewing* turned from the end of one survey line to the start of the next, it was necessary to make a slow turn to avoid possible entanglement of the 1.5-km-long hydrophone streamer towed behind the vessel. The full array of airguns remained in the water during turns from one line to the next, although the number of airguns firing was reduced from 3 to 2 airguns, also a requirement of the IHA (see Chapter 3 and Appendix A). Operation of the airguns during turns allowed the subsequent resumption of geophysical data collection without needing to implement the 30 min observation and ramp-up requirements of the IHA (see Chapter 3 and Appendix A).

Other Types of Airgun Operations

Airguns operated during certain other periods besides periods with production seismic operations and line changes during the ETPCA cruise. Airguns were operated during ramp ups, power downs, periods of equipment repair, and testing of the airguns. Ramp ups involved a systematic increase in the number of airguns firing; one GI gun was added every 5 min, to ensure that the source level of the array increased in steps not exceeding 6 dB per 5-min period. Ramp ups were required by the IHA (see Chapter 3 and Appendix A). Ramp ups occurred when operations with the 3 GI guns commenced after a period without airgun operations, and after periods when only one GI gun had been firing (e.g., after a power down for a marine mammal or sea turtle).

TABLE 2.2. Specifications of the array of 3 GI guns used during the ETPCA seismic study. Two different configurations were used: three 105 in^3 GI guns or three 45 in^3 GI guns.

Energy source [a]	3 GI guns, each of 105/105 in^3 or 45/45 in^3.
Source output (downward) [b]	0-pk is 10.8 bar-m (240.7 dB re 1 μPa·m); pk-pk is 21 bar-m (246.4 dB)
Towing depth of energy source	2.5 m
Total generator air discharge volume	315 or 135 in^3
Dominant frequency components	30–140 Hz
Airgun positions used	Three side-by-side GI-guns 7.8 m apart

[a] The two values (e.g., 105/105 in^3) refer to the generator and injector volumes.

[b] Source level estimates are based on a filter bandwidth of ~0–250 Hz.

Multi-beam Bathymetric Sonar, Sub-bottom Profiler, and Fathometer

Along with the GI-airgun operations, three additional acoustic systems operated during the cruise. A 15.5-kHz Hydrosweep MBB sonar and a 3.5-kHz sub-bottom profiler operated throughout most of the cruise to map the bathymetry and sub-bottom conditions, as necessary to meet the geophysical science objectives. During seismic operations, these sources typically operated simultaneously with the GI guns. In addition, a standard 10.5-kHz depth sounding sonar (i.e., fathometer or echosounder) was used occasionally for safety purposes when the *Ewing* was operating in shallow areas where the water depths were not well charted and near ports. This type of sonar is routinely employed by sea-going vessels to monitor water depths. The various sonars are described in further detail in Appendix C.

3. MONITORING AND MITIGATION METHODS

This chapter describes the marine mammal and sea turtle monitoring and mitigation measures implemented for L-DEO's ETPCA seismic study, addressing the requirements specified in the IHA and ITS (Appendix A). The section begins with a brief summary of the monitoring tasks relevant to mitigation for marine mammals and sea turtles. The acoustic measurements and modeling results used to identify the safety radii for marine mammals and turtles are then described. A summary of the mitigation measures implemented and updated during the cruise is then presented. The section ends with a description of the marine mammal and sea turtle monitoring methods implemented for this cruise from aboard the *Ewing*, and a description of data analysis methods.

On 21 Nov. 2004, L-DEO requested a clarification of the mitigation measures for sea turtles identified in the project IHA and ITS (Appendix A), and received a response from NMFS on 23 Nov. In addition, the mitigation measures for sea turtles were modified during the cruise on 30 Nov. 2004 (with notification to NMFS), to ensure that the procedures could be practically implemented during the seismic survey. These modifications are described in the sections that follow.

Monitoring Tasks

The main purposes of the vessel-based monitoring program were to ensure that the provisions of the IHA and ITS issued to L-DEO by NMFS were satisfied, effects on marine mammals and sea turtles were minimized, and residual effects on animals were documented. The objectives of the monitoring program were listed in Chapter 1 *Mitigation and Monitoring Objectives*. Tasks specific to monitoring are listed below (also see Appendix A):

- Provide qualified MMOs for the *Ewing* source vessel throughout the ETPCA seismic survey.
- Visually monitor the occurrence and behavior of marine mammals and sea turtles near the airgun array whether the airguns were operating or not.
- Record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals and turtles.
- Use passive acoustic monitoring (PAM) to detect calling marine mammals whenever water depths permitted, and notify visual observers of nearby marine mammals.
- Use the monitoring data as a basis for implementing the required mitigation measures.
- Estimate the number of marine mammals potentially exposed to airgun sounds.

Safety and Potential Disturbance Radii

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB re 1 µPa (rms) for cetaceans and ≥190 dB re 1 µPa (rms) for pinnipeds. In addition, for this project, NMFS specified, in the Incidental Take Statement (ITS) issued in conjunction with the IHA, that the safety criterion for sea turtles would be 170 dB (rms). These safety criteria are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these animals or impair their hearing abilities, but that higher received levels *might* have some such effects. Marine mammals exposed to ≥160 dB (rms) are assumed to be potentially subject to behavioral disturbance, although for certain groups (dolphins, pinnipeds) this is unlikely to occur unless received levels are higher, perhaps ≥170 dB rms (see Chapter 1).

Radii within which received levels were expected to diminish to the various values mentioned above (i.e., 190, 180, 170 and 160 dB re 1 μPa rms) have been estimated by L-DEO. This was done based on a combination of acoustic modeling, as summarized in LGL Ltd. (2004a,b), and empirical measurements of sounds from several airgun configurations involving 2–20 airguns (Tolstoy et al. 2004a,b). The results from the empirical study were limited in various ways, and do not include measurements for 3 GI guns. However, the empirical data for other airgun systems with 2–20 airguns showed that water depth affected the radii within which the received level would exceed any specific level such as 180 or 170 dB re 1 μPa (rms).

For mitigation purposes during the ETPCA study, three strata of water depth were distinguished: deep (>1000 m), intermediate (100–1000 m), and shallow (<100 m). These water depth strata, with associated differences in the 190, 180, 170 and 160 dB radii, have also been recognized during other recent L-DEO seismic cruises (e.g., Smultea et al. 2004, 2005; MacLean and Koski 2005). Background on the results of the acoustic calibration study and sound modeling, in relation to these depth strata, is provided in Appendix B.

The safety radii for the 3-GI-gun array and for one GI gun are shown in Table 3.1. Many of these safety radii are probably somewhat overestimated and precautionary but were recommended by L-DEO and/or selected by NMFS for the ETPCA IHA (Appendix A). These safety radii were implemented during the cruise. However, updated estimates of the radii at which GI-gun sounds would diminish to 190, 180, 170 and 160 dB re 1 μPa (rms) were used to estimate the numbers of marine mammals potentially exposed to these received GI gun sound levels. This procedure is further discussed under *Analyses*, later in this chapter.

TABLE 3.1. Safety radii around the 3-GI-gun array and single GI gun as applied for sea turtles (based on 170-dB criterion), cetaceans (180-dB), and pinnipeds (190-dB). These 170, 180 and 190 dB distances were estimated by L-DEO (LGL Ltd. 2004a,b). The new requirement to use the 170 dB criterion for sea turtles was specified in the Incidental Take Statement (ITS) issued by NMFS in conjunction with the project IHA (see Appendix A).[a]

Airgun configuration	Water depth	Safety radius for sea turtles (170 dB)	Safety radius for cetaceans (180 dB)	Safety radius for pinnipeds (190 dB)
3 GI guns	>1000 m	265	82	26
"	100–1000 m	398	123	39
"	<100 m	1325	574	390
1 GI gun	>1000 m	90	27	10
"	100–1000 m	135	41	15
"	<100 m	375	189	150

[a] The safety radius for cetaceans was changed during the first few days of the cruise, with permission from NMFS, to account for the size of the airgun array to be used. The safety radii for the 315 in^3 array of 3 GI guns remained 82, 123, and 574 m, as listed above. The radii for the 135 in^3 array of 3 GI guns were 62, 93, and 433 m, respectively.

There were times when the full 3-GI-gun array was deployed but fewer than three airguns were firing (e.g., during turns between lines). At these times, the full safety radius for the 3-GI-gun array was assumed to apply, regardless of the number of GI guns firing. The one exception was any period when there was a power down to one GI gun. For determination of shut-down radii in the field and also during data analysis, we differentiated between one GI gun operating and more than one GI gun operating.

Mitigation Measures as Implemented

The primary mitigation measures that were implemented during the ETPCA cruise included ramp up, power down, and shut down of the GI guns. These three standard measures are described in detail in Appendix D. Mitigation also included those measures specifically identified in the IHA and ITS dated 19 Nov. 2004 (see Appendix A).

Standard Mitigation Measures

Standard mitigation measures implemented during the study included the following:

1. The 3-GI-gun system used during the ETPCA cruise was a relatively small seismic source in terms of both number of GI guns (max. 3) and total generator volume (max. 315 in^3). This source was judged to be the smallest that could be used while still meeting the scientific objectives of the geophysicists conducting the ETPCA study. The small number of guns and the small source volume decreased the sound level produced by the GI guns, and thus the exposure of marine mammals and sea turtles to GI gun sounds. The sound pressure produced by a GI gun array generally varies as a direct function of the number of guns, and with the cube root of total array volume, if other factors are held constant (Caldwell and Dragoset 2000).
2. At times during the cruise, the geophysicists determined that their objectives could be met with a smaller source, and the generator volume was reduced from 105 to 45 in^3 per GI gun (i.e., total generator volume reduced from 315 in^3 to 135 in^3). This further reduced the amount of sound emitted from the source.
3. The configuration of the array directed more sound energy downward, and to some extent fore and aft, than to the side of the track. This reduced the exposure of marine animals, especially to the side of the track, to GI gun sounds.
4. Safety radii implemented for the ETPCA cruise varied with water depth based on results of the acoustic calibration study conducted from the *Ewing* in the Gulf of Mexico in 2003 (Tolstoy et al. 2004a,b), as discussed earlier in this chapter and in Appendix D.
5. Power-down or shut-down procedures were implemented when a marine mammal or turtle was sighted within or near the applicable safety radius while the GI guns were operating.
6. A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius. However, substantial alteration of vessel course or speed was not feasible during the ETPCA cruise given the length (>1.5 km) of the streamer being towed. Power downs or shut downs were the preferred mitigation measures when mammals or turtles were sighted within or about to enter the safety radii.
7. Ramp-up procedures were implemented whenever the 3-GI-gun array was powered up, to gradually increase the size of the operating source at a rate no greater than one additional GI gun per 5 minutes. This would be an increase in source level of ≤6 dB per 5 minutes—the maximum ramp-up rate authorized by NMFS during past L-DEO seismic cruises.

8. Ramp up could not proceed if marine mammals or sea turtles were known to be within the safety radii, or if there had been visual detection(s) inside the safety zone within the following periods: 30 min for mysticetes, sperm whales, and beaked whales; 15 min for small odontocetes; or 4–10 min for sea turtles. (The period for sea turtles was initially 30 min, but this was amended on 30 Nov.—see *Updates…,* below.)
9. The volume of the GI gun array was reduced from 3 GI guns to 2 GI guns during vessel turns (line changes).

Special Mitigation Measures for this Cruise

10. At the start of GI gun operations, seismic lines were run from shallow water towards deeper water if possible, to reduce the risk of 'trapping' animals in bays or coastal areas.
11. For sea turtles, the safety radii were the estimated 170 dB radii, as required by the ITS issued by NMFS for this cruise (Appendix A). The safety radii used for sea turtles were the 170 dB radii for the 315 in^3 3-GI-gun array even during times when the 135 in^3 3-GI-gun array was in use.
12. The safety radii for one GI gun were estimated based on the 180 and 170 dB radii around a 105 in^3 single GI gun, even during times when a single 45 in^3 GI gun was in use.

Updates to Monitoring and Mitigation Measures during the Cruise

Some mitigation measures specified in the IHA or ITS were amended, in consultation with NMFS, after considering the small size of the 3-GI-gun array and the fact that some of the seismic operations were not in areas adjacent to turtle nesting beaches. The amended procedures still met the objectives identified in the IHA and ITS issued to L-DEO on 19 Nov. 2004 (see Appendix A), but with less disruption to the geophysics objectives that would have occurred without these amendments. Appendix A lists the original requirements of the IHA and ITS. This section identifies the updates that were made to address the resulting logistical problems. More detailed descriptions of mitigation and monitoring measures can be found in Appendix D.

13. Continuous nighttime observations for sea turtles were required during the ETPCA seismic cruise according to the ITS issued by NMFS for this project. This was the second time that such a requirement was specified by NMFS for an L-DEO seismic cruise. The first had been during the Southeast Alaska cruise in Aug.–Sept. 2004—see MacLean and Koski (2005). However, the present cruise was the first when regular nighttime observations were required, via the ITS, because of concern for sea turtles. The IHA and ITS required MMOs to be on watch whenever the seismic array was operating and to increase the nighttime observer coverage to equal or exceed the daytime observer coverage. The MMO complement (five MMOs) had been selected on the assumption that only limited nighttime visual observations would be required, as in most previous L-DEO seismic surveys. Five observers could not conduct 24 h visual as well as 24 h acoustic monitoring. To address the primary objective of the IHA/ITS requirement for nighttime visual monitoring (detection of sea turtles), priority areas for nighttime observations were identified by L-DEO, with approval from NMFS on 23 Nov. 2004.
14. The priority areas for nighttime observations were mainly adjacent to turtle nesting beaches, i.e., Grids 2 and 3, Southern Sandino Basin and Nicoya Penin., as well as Grid 4 in the Gulf of Fonseca (see Fig. 1.1). In those areas, visual observations were maintained during day and night, with a commensurate reduction in PAM effort in order to maximize visual effort for sea turtles in these priority areas. However, night observations were also conducted in Grid 1 after days when several sea turtles had been sighted, provided that sea state conditions allowed for good sightability at night.

No nighttime observations were conducted during the first night after seismic operations commenced in Grid 3 (22 Nov.) because the mitigation measures were not clarified by NMFS until 23 Nov.

15. Initially, as specified by the IHA and ITS, ramp up could not proceed until 30 min after the most recent visual detection of sea turtle(s) inside the safety zone. However, the 30-min period for turtles appeared unnecessarily conservative. The safety radii for the small GI gun array used during this project were small (Table 3.1). A turtle that was initially seen near the GI guns would be well outside the safety radius in considerably less than 30 min, given the typical 7–9 km/h (4–5 kt) speed of the *Ewing* during seismic operations. Starting on 30 Nov. 2004, this 30 min requirement was modified to 4 min in intermediate and deep (>100 m) water, and 10 min in shallow (<100 m) water.

Visual Monitoring Methods

Visual monitoring methods were designed to meet the requirements identified in the IHA and the ITS (see above and Appendix A). The primary purposes of MMOs aboard the *Ewing* were as follows: ***(1)*** Conduct monitoring and implement mitigation measures to avoid or minimize exposure of marine mammals and sea turtles to airgun sounds with received levels >180 and >170 dB re µPa (rms), respectively. ***(2)*** To document numbers present and any reactions to seismic activities. The data collected were used to estimate the number of marine mammals potentially affected by the project. Results of the monitoring effort are presented in Chapter 4.

The visual monitoring methods that were implemented during this cruise were very similar to those during previous L-DEO seismic cruises. In chronological order, those were described by Smultea and Holst (2003a,b), MacLean and Haley (2004), Holst (2004), Smultea et al. (2004), Haley and Koski (2004), MacLean and Koski (2005) and Smultea et al. (2005). The standard visual observation methods are described in Appendix D

In summary, during the ETPCA survey at least one MMO maintained a visual watch for marine mammals and sea turtles during all daylight hours from dawn to dusk. During this cruise, two visual observers were on duty for 57% of the time when visual watches were underway. Visual observations were conducted from the *Ewing*'s flying bridge or (during inclement weather) from the bridge. Nighttime watches were conducted by at least one MMO for 30 min prior to and during nighttime ramp-ups as specified in the IHA (see Appendices A and D). Nighttime watches were also conducted near sea turtle nesting areas (see *Updates…,* above). Observers focused search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches during the day were conducted with the naked eye, Fujinon 7 × 50 reticle binoculars, and mounted "Big-eyes" 25 × 150 binoculars (Appendix D).

Nighttime observations were conducted with image-intensifying Night Vision Devices (NVDs): ITT Industries Night Quest NQ220 "Night Vision Viewer". These were "Generation 3" binocular devices that provided 4× magnification and a field of view of about 40°. The distances to which these NVDs are effective for observing marine mammals and sea turtles at sea during the night are not well known. Results of four previous tests of their effectiveness were reported in Smultea and Holst (2003), Holst (2004), Smultea et al. (2004), and MacLean and Koski (2005). These results from the various tests to date suggest that the effectiveness of the Night Quest NA220 NVDs is affected by target color, ambient light (moon), sea conditions, and environmental conditions (rain). It appears that the NVDs may at times be useful to distances up to ~250 m in relatively calm conditions, but their effective distance is reduced by high Beaufort states and inclement weather. The ETPCA cruise was the first time that MMOs first detected cetaceans—all delphinids—at night using the NVDs. In total, to date, five separate nighttime sightings of delphinids have been obtained by MMOs aboard the *Ewing* based on use of the NVDs. Four of these nighttime sightings occurred during this ETPCA cruise as described in Chapter 4. See Appendix D for further details regarding visual monitoring methods by day and night.

Passive Acoustic Monitoring Methods

Passive acoustic monitoring (PAM) was conducted to complement the visual monitoring program as required in the IHA (Appendix A). A requirement for PAM was first specified by the IHA issued to L-DEO during spring 2004 for a *Ewing* seismic cruise in the SE Caribbean (Smultea et al. 2004). PAM was again required and conducted for L-DEO's Blanco seismic cruise in pelagic waters off Oregon in autumn 2004 (Smultea et al. 2005). Visual monitoring typically is not effective during periods of bad weather or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Acoustical observations can be used in addition to visual observations to improve detection, identification, localization, and tracking of cetaceans.

In practice, acoustic monitoring served to alert visual observers when vocalizing cetaceans were in the area. The SEAMAP PAM system aboard the *Ewing* was often capable of detecting calling cetaceans before they were seen by visual observers and even if they were not sighted at all by visual observers. This helped to ensure that cetaceans were not nearby when seismic operations were underway or about to commence. The acoustical system was usually monitored in real time so that the visual observers could be advised when cetaceans were detected, as directed in the IHA. This approach had been implemented successfully aboard the *Ewing* during L-DEO's 2004 SE Caribbean and Blanco seismic cruises (Smultea et al. 2004, 2005).

The SEAMAP (Houston, TX) system was the primary acoustic monitoring system used during the seismic cruise, as during L-DEO's SE Caribbean and Blanco seismic surveys (see Appendix D for a description of this system). The lead-in from the hydrophone array was ~300 m long, and the active part of the hydrophone array was 56 m long. During the ETPCA survey, the hydrophone array was towed at a depth of ~20 m due to shallow water depths in some parts of the study area. Due to some problems with the SEAMAP software, acoustic monitoring software developed by CIBRA (University of Pavia, Italy) was used to record cetacean calls detected by the SEAMAP hydrophones (Pavan 2005; see Appendix D).

The acoustical array was monitored nearly 24 h per day while at the seismic survey area during airgun operations and during most periods when airguns were off. While at the survey area, the array was typically used in combination with visual monitoring, whether airguns were operational or not. During times when PAM effort had to be reduced because of the IHA/ITM requirement for increased nighttime visual effort, unattended acoustic recordings were made; these were later reviewed.

One MMO monitored the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the map-based database viewer for frequency ranges produced by cetaceans. MMOs monitoring the acoustical data were usually on shift for 1–2 h, with the exception of one person who was usually on duty for 6 h through the night to allow the visual observers to obtain 8 h of sleep. All five MMOs rotated through the PAM position, although the most experienced with acoustics was on PAM duty more frequently.

When cetacean calls were heard, the visual observers on the flying bridge or bridge were immediately notified of the presence of calling marine mammals. Each acoustic "encounter" was assigned a chronological identification number. An acoustic encounter was typically defined as including all calls of a particular species or species-group separated by <1 h (Manghi et al. 1999).

Analyses

Categorization of Data

The study area for the purposes of marine mammal and sea turtle data analyses was the actual seismic survey area plus the transits from Costa Rica and to Panama. These areas are characterized by similar ranges of water depths, and occur within the Central American Coastal Province of the Pacific Coastal Biome (Longhurst 1998). This biome extends from the tip of Baja California to Equador.

Visual and acoustic effort, as well as marine mammal sightings and acoustic detections, were divided into several analysis categories related to vessel and seismic activity. The categories used were similar to those used during recent L-DEO seismic studies (e.g., Haley and Koski 2004; MacLean and Koski 2005; Smultea et al. 2005). These categories are defined briefly below, with a more detailed description provided in Appendix D.

In general, data were categorized as "seismic" or "non-seismic". "Seismic" includes all data collected while the GI guns were operating, including ramp ups, and periods up to 1.5 min after the GI guns were shut off. Non-seismic includes all data obtained before airguns were turned on (pre-seismic) or >2 h after GI guns were turned off. Data collected during post-seismic periods from 1.5 min to 2 h after cessation of seismic were considered "recently exposed" (1.5–30 min) or "potentially exposed" (30 min–2 h) to seismic, and were excluded from analyses. Thus, they were not included in either the "seismic" or "non-seismic" categories.

This categorization system was designed primarily to distinguish situations with ongoing seismic surveys from those where any seismic surveys were sufficiently far in the past that it can be assumed that they had no effect on current behavior and distribution. The rate of recovery toward "normal" during the post-seismic period is uncertain. Therefore, the post-seismic period was defined so as to be sufficiently long (2 h) to ensure that any carry-over effects of exposure to airgun sounds surely would have waned to zero or near-zero. The reasoning behind these categories was explained in MacLean and Koski (2005) and Smultea et al. (2005) and is discussed in Appendix D.

Line Transect Estimation of Densities

Marine mammal sightings during the "seismic" and "non-seismic" periods were used to calculate sighting rates (#/km). Sighting rates were then used to calculate the corresponding densities (#/km^2) of marine mammals near the survey ship during seismic and non-seismic periods. Density calculations were based on line transect principles (Buckland et al. 2001). Because of assumptions associated with line-transect surveys [sightability, $f(0)$, $g(0)$, etc.], only those daylight periods during which the *Ewing* was traveling at speeds ≥3.7 km/h (2 kt) were considered "useable" effort. Useable data included effort and sightings both within the seismic survey area and during transit to and from that area. "Useable" data were limited to the survey effort and marine mammal sightings obtained with Beaufort Wind Force ≤5. For cryptic species such as beaked whales, *Kogia* spp., and minke whales, analyses considered only the sightings and effort during Beaufort Wind Force ≤2. Useable periods excluded those 90 s to 2 h after guns were turned off (post-seismic), poor visibility conditions (visibility <3.5 km), and periods with >60º of severe glare between 90º left and 90º right of the bow. Because of the low number of sightings of any individual species, and the inability to assess trackline sighting probability during a study of this type, correction factors for missed animals, i.e., $f(0)$ and $g(0)$, were taken from other related studies, as summarized by Koski et al. (1998) and Ferguson and Barlow (2001).

Densities during *non-seismic* periods were used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during *seismic* periods were used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. The difference between the two estimates could be taken as an estimate of the number of animals that moved in response to the operating seismic vessel, or that changed their behavior sufficiently to affect their detectability to visual observers. Further details on the line transect methodology used during the survey are provided in Appendix D.

Analyses of marine mammal behavior in "seismic" vs. "non-seismic" conditions were also limited to "useable" sightings and effort.

Estimating Numbers Potentially Affected

For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 µPa (rms) may have been disturbed. When calculating the number of mammals potentially affected, the estimated 160 dB radii for the relevant water depth and for the number of airguns then in use (1, 2 or 3 GI guns) were applied (see Table 4.8 *in* Chapter 4). We also allowed for the expected differences in 160 dB radii when the GI gun(s) then in use were 45 in^3 vs. 105 in^3 GI guns (Table 4.8). Most commonly, the source consisted of 3 GI guns with total volume 135 in^3. Of 5318 km of transect with GI guns operating, 3 GI guns with this volume were operating for 3979 km.

Two approaches were applied to estimate the numbers of marine mammals that may have been exposed to sound levels ≥160 dB re 1 µPa (rms):

1. Estimates of the numbers of potential *exposures* of marine mammals, and
2. Estimates of the number of different *individual* mammals exposed (one or more times).

The first method ("exposures") was obtained by multiplying the following three values for each airgun configuration in use: (***A***) km of seismic survey. (***B***) Width of area assumed to be ensonified to ≥160 dB (2 × 160 dB radius), depending on gun configuration and water depth (Tables 3.1, 3.2). (***C***) "Corrected" densities of marine mammals estimated by line transect methods.

The second approach ("individuals") involved multiplying the corrected density of marine mammals by the area exposed to ≥160 dB one or more times during the course of the study. In this method, areas ensonified to ≥160 dB on more than one occasion, e.g., when seismic lines crossed, were counted only once.

The two approaches can be interpreted as providing minimum ("individual") and maximum ("exposure") estimates of the number of marine mammals exposed to sound levels ≥160 dB re 1 µPa (rms). The actual number exposed is probably somewhere between these two estimates. This approach was originally developed to estimate numbers of seals potentially affected by seismic surveys (Harris et al. 2001), and has recently been used in various L-DEO reports to NMFS (e.g., Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005). The methodology is described in detail in these past reports and in Appendix D.

4. MARINE MAMMALS

Introduction

This chapter provides background information on the occurrence of marine mammals in the project area, and describes the results of the marine mammal monitoring program. In addition, the number of marine mammals potentially affected during project operations is estimated. Results of the sea turtle monitoring program are presented in Chapter 5. Preliminary results of the geophysical studies conducted aboard the *Ewing* during this project are summarized in Fulthorpe and McIntosh (2005).

Seismic operations were conducted along 5318 km of trackline over a total of 651 h (Fig. 4.1; Table ES.1). In total, 4965 km of visual observations and 5200 km of passive acoustic monitoring effort (i.e., PAM) were conducted. "Useable" survey conditions occurred during 55% of the total visual effort (Fig. 4.2). "Useable" effort included effort within and during transit to and from the seismic survey area. It excluded periods 90 s to 2 h after guns were turned off, nighttime observations, poor visibility conditions (visibility <3.5 km), and Beaufort sea state >5 (>2 for cryptic species). Periods when the *Ewing*'s speed was <3.7 km/h (2 kt) were also excluded. The project has provided survey data on the occurrence of marine mammals and sea turtles in a localized area near the Pacific coasts of northern Costa Rica, Nicaragua, and Honduras in the Eastern Tropical Pacific Ocean (ETP) during late fall/early winter.

The marine mammals known to occur in the study area belong to three taxonomic groups: odontocetes (toothed cetaceans, such as dolphins and sperm whales), mysticetes (baleen whales), and pinnipeds (seals and sea lions). A total of 34 cetacean species and 6 species of pinnipeds are known to or may occur in the ETPCA (Appendix E.1). Of the 34 cetacean species, 27 are likely to occur in the survey area. Five of those 27 cetacean species are listed under the U.S. Endangered Species Act (ESA) as endangered: sperm whales, humpback whales, blue whales, fin whales, and sei whales. Appendix E.1 summarizes the abundance, habitat, and conservation status of the 27 cetacean species likely to occur in the survey area.

Although marine mammal populations in the survey area have not been studied in detail, several studies of marine mammal distribution and abundance have been conducted in the wider ETP. These data were collected mainly via a series of wide-ranging ship-based surveys (e.g., Polacheck 1987; Wade and Gerrodette 1993; Ferguson and Barlow 2001). A review of these studies as relevant to the ETPCA survey area was provided in the project IHA application and EA (LGL 2004a,b). The estimated densities of marine mammals in the ETPCA study area are shown in Appendix E.2 based on information available prior to the present project (e.g., Ferguson and Barlow 2001). However, these densities are based on survey data collected from late July to early Dec., whereas the ETPCA survey occurred during Nov.–Dec. The presented densities are corrected for detectability biases using $f(0)$ and $g(0)$ values from Koski et al. (1998) and Ferguson and Barlow (2001), unless otherwise noted.

Monitoring Effort and Cetacean Encounter Results

This section summarizes the visual and acoustic monitoring effort and sightings/detections from the *Ewing* during the ETPCA seismic cruise from 21 Nov. to 22 Dec. 2004. The study area for the purposes of marine mammal and sea turtle data analyses was the actual seismic survey area plus the transits from Costa Rica and to Panama (see Fig. 1.1 and Chapter 3 *Analyses*). The data categories and definitions used for these analyses were discussed in Chapter 3. Survey effort herein is reported primarily in kilometers. Visual and acoustic monitoring results are presented separately, with detailed data summaries presented in Appendix F, including survey effort in both kilometers and hours.

Visual Survey Effort

All *Ewing* survey tracks are plotted by seismic activity (GI guns on or off) in Figure 4.1 and by visual survey effort (useable, non-useable, none) in Figure 4.2. A summary of visual effort and total *Ewing* operations is shown in Table ES.1. A total of 2734 km of useable visual observations were made during the cruise (Table ES.1). Most (84%) of this effort occurred within the seismic survey grids, with the remainder occurring during transits while the GI guns were off. Useable survey effort, subdivided by airguns on or off and water depth strata, is shown in Appendix F.1. The majority (63%) of the useable observation effort occurred while the *Ewing* was in intermediate (100–1000 m) water depths. Most (82%) useable observation effort occurred while the GI guns were firing (Appendix F.1).

Nearly one-third (31%) of all visual effort occurred at night; however, nighttime watches were excluded from "useable" data (Table ES.1). All nighttime observations were associated with mitigation during seismic operations, either while the GI guns were firing in specified "priority" sea turtle areas or before and during ramp-up, as described in Chapter 3 (also see Appendix A). Two observers were on watch during 57% of useable visual watches, and one observer was on watch during the remaining 43%. MMOs observed primarily (>99% of all useable watches) from the flying bridge, with the remaining watches conducted from the bridge.

Beaufort Wind Force (Bf) during observations ranged from 1 to 7, with 87% of the observations being with Bf ≤5 (i.e., useable). Nearly one-half (49%) of the useable observation effort (Bf 1 to 5) occurred during Bf 3 or less (wind speed 0.0–5.1 m/s); the remaining 51% occurred during Bf 4 or 5 (Appendix F.2).

Visual Sightings of Marine Mammals and Other Vessels

***Numbers of Marine Mammals Seen*.**—Cetaceans were the only marine mammals seen during the cruise. A detailed list of all sightings and associated sighting information is located in Appendix F.3. An estimated total of ~2091 individual cetaceans were seen in 81 groups during the entire study period (Fig. 4.2, Appendix F.4). This total represents all cetaceans sighted during all times when the marine mammal observers were "on watch", regardless whether or not the cetaceans were sighted during "useable" survey conditions. (The term "sighting" herein refers to a group of one or more individuals.) Most sightings (84% or 68 groups) were useable (Tables 4.1 and 4.2). Similarly, most (96% or 2004) individual cetaceans seen were included in useable sightings. These "useable sightings", along with the corresponding effort data, are the basis for the ensuing analyses comparing sighting rates, behaviors, and densities of marine mammals during seismic and non-seismic periods.

At least nine species of cetaceans were identified during the cruise and several sightings were made of unidentified whales and dolphins; these unidentified cetaceans may represent additional species (Appendix F.4). However, only eight of the nine species were represented by "useable" sightings, as the one sighting of a minke whale was excluded from analyses because it was seen during "non-useable" effort. All of the identified species have been documented in previous studies as occurring in the ETPCA (Appendix E); however, minke whales are considered rare in the region, as discussed in the project EA (LGL Ltd. 2004a). Considering all sightings ("useable" or not) during the entire cruise, the pantropical spotted dolphin (n = 13 sightings) and humpback whale (n = 11) were the most commonly sighted cetacean species, followed by the bottlenose dolphin (n = 8 sightings; Appendix F.4). On an individual basis, many more spinner dolphins (n = 1350 individuals) were seen than any other cetacean species. Humpback whales and a single minke whale were the only baleen whales identified to species during the cruise. An additional four groups of unidentified whales were seen, including one group of four unidentified toothed whales (Table 4.2 and Appendix F.4).

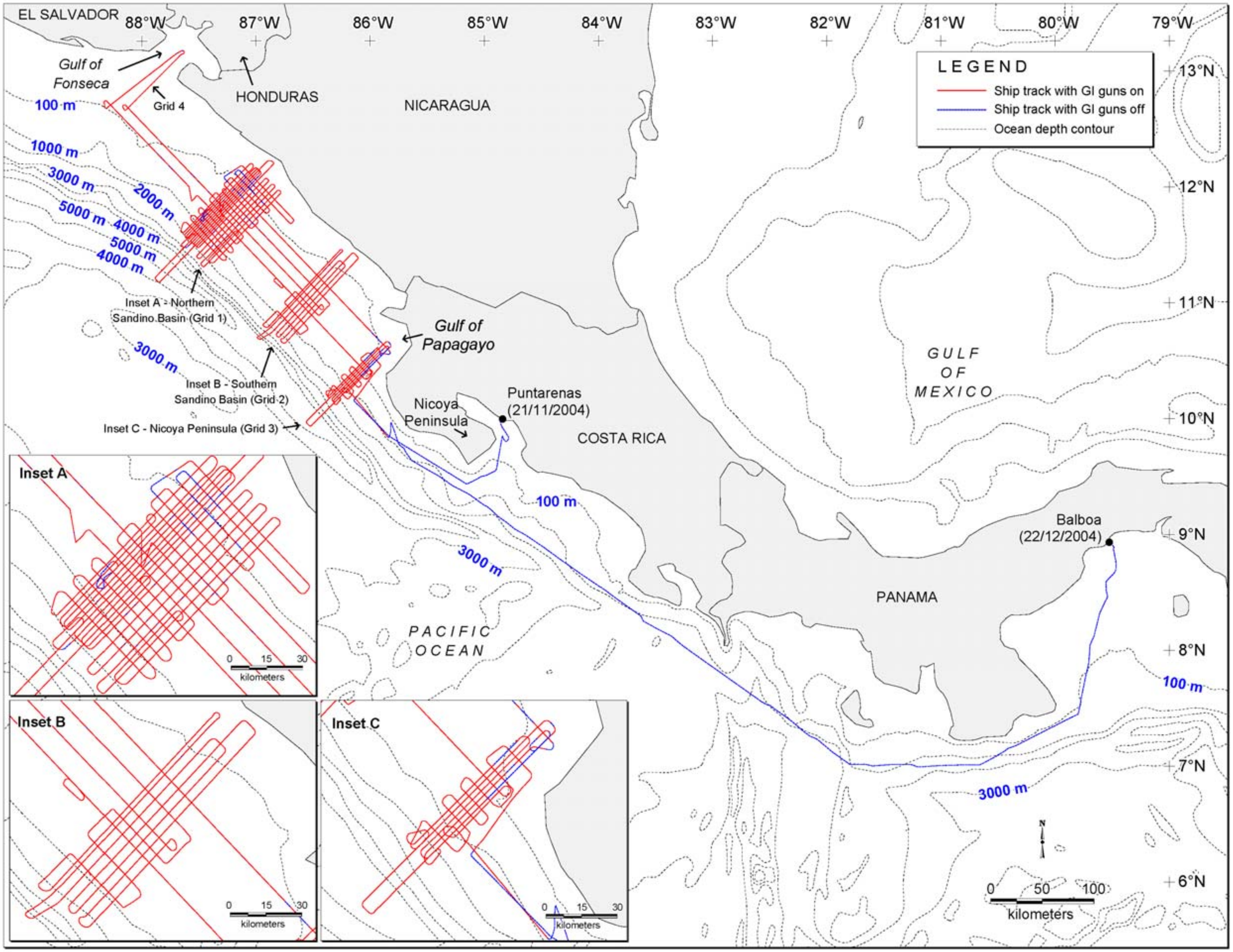

FIGURE 4.1. The study area and *Ewing* ship tracks showing periods when GI guns were on and off during the ETPCA seismic survey, 21 Nov. – 22 Dec. 2004. The cruise originated in Costa Rica and ended in Panama.

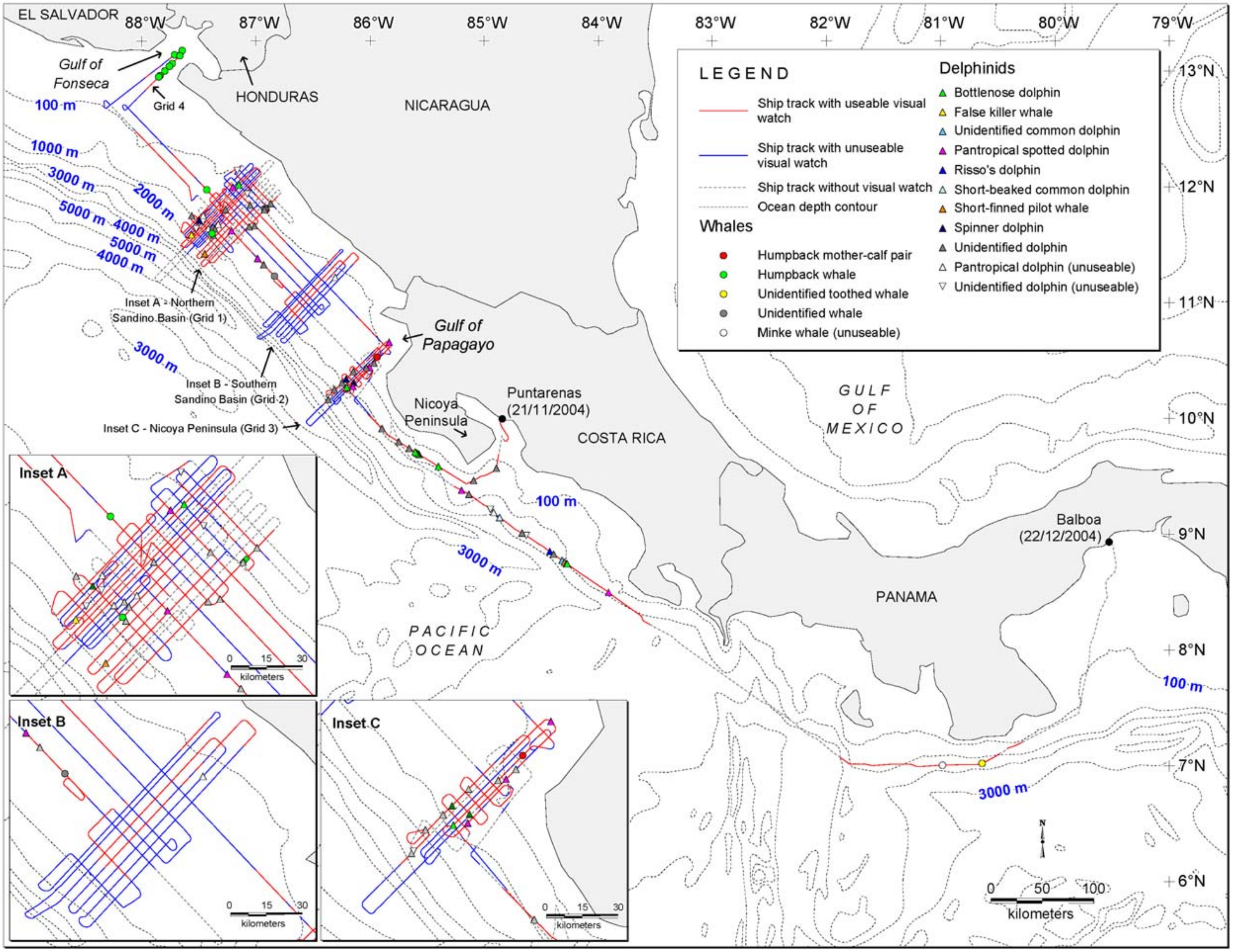

FIGURE 4.2. Locations of all cetacean sightings made during the ETPCA seismic cruise showing periods with useable vs. non-useable visual effort, 21 Nov. – 22 Dec. 2004.

TABLE 4.1. Number of useable[1] sightings and individual cetaceans observed from the *Ewing* during the ETPCA seismic cruise, 21 Nov.–22 Dec. 2004. No pinnipeds were sighted. Species listed as Endangered under the U.S. ESA are indicated by italics.

	Seismic		Non-seismic		Total Useable	
	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.
Odontocetes						
Delphinids						
Bottlenose dolphin	2	19	6	50	8	69
Pantropical spotted dolphin	5	187	3	22	8	209
Spinner dolphin	3	1350			3	1350
Short-beaked common dolphin			1	45	1	45
Unidentified common dolphin			1	15	1	15
Risso's dolphin			1	25	1	25
False killer whale	1	12			1	12
Short-finned pilot whale	1	5	3	25	4	30
Unidentified dolphin	16	82	10	144	26	226
Mysticetes						
Humpback whale	11	16			11	16
Minke whale [2]						
Unidentified mysticete						
Unidentified Whales [3]	3	3	1	4	4	7
Total Cetaceans	**42**	**1674**	**26**	**330**	**68**	**2004**

[1] Useable sightings are those made during useable daylight periods of visual observation, as defined in *List of Acronyms and Abbreviations*. An additional 13 cetacean sightings (82 individuals) are excluded from this Table because they were sighted during non-useable survey conditions. See Appendix F.3 for a list of all cetacean sightings, by species, during both useable and non-useable survey conditions.

[2] One minke whale is excluded from this Table because it was seen during non-useable survey conditions (see Appendix F.3).

[3] Unidentified Whales includes unidentified toothed whales and unidentified whales. It excludes mysticetes listed above.

Nighttime Sightings of Cetaceans.— For the first time during an L-DEO seismic survey, cetaceans were initially seen at night with the NVDs. The only other *Ewing* seismic cruise where nighttime visual detections of marine mammals were made by MMOs was in the Gulf of Alaska, when a group of Dall's porpoises was first heard splashing then seen via the NVDs and naked eye near the bow (MacLean and Koski 2005). A total of six nighttime visual detections were made during the ETPCA cruise, two of which were seen through the NVDs. All nighttime sightings were of small groups (2–8 individuals) of pantropical spotted or unidentified dolphins. All six groups were seen near the *Ewing*'s bow while 3 GI guns with volume 135 in^3 were operating in Bf 1–4.

Because nighttime sightings of cetaceans have been virtually non-existent during previous *Ewing* seismic cruises, the six ETPCA nighttime sightings are described in detail below. Previous to the Gulf of Alaska and ETPCA cruises, nighttime visual effort occurred only during the short periods (~1–2 h) associated with occasional nighttime ramp-ups from one airgun. However, for the Alaska and ETPCA cruises, extended nighttime visual effort with NVDs was required by NMFS. During the present cruise, nighttime observations were required near turtle nesting areas (see Chapter 3). While four ground-truthing experiments have been done with the NVDs to evaluate how far MMOs are able to see various targets, the effectiveness of the NVDs for seeing actual cetaceans at night has previously been questionable due to the lack of nighttime sightings. The nighttime sightings made during the Gulf of Alaska and ETPCA cruises

TABLE 4.2. Number of visual and acoustic detections of cetacean groups made from the *Ewing* during the ETPCA cruise (including transits and nighttime), 21 Nov. – 22 Dec. 2004. Numbers in parentheses are numbers of individuals. For species with some non-useable[a] visual sightings, the useable sightings are shown in parenthetical bold italics. For acoustic detections, group size was unknown except in the cases with concurrent visually-matched sightings.

Species	***Ewing* Visual-Only Sightings (# indiv)**	***Ewing* Acoustic-Only Detections**	**Matched *Ewing* Visual/ Acoustic Detections (# indiv)**	**Total**	
				Visual Sightings (# indiv)	**Acoustic Detections**
Bottlenose dolphin	6 (50)	-	2 (19)	8 (69)	2
Pantropical spotted dolphin	5 (38) ***4 (23)***	-	8 (200)[b] ***4(186)***	13 (243) ***8 (209)***	14[c]
Spinner dolphin	-	-	3 (1350)	3 (1350)	3
Short-beaked common dolphin	1 (45)	-	-	1 (45)	-
Unidentified common dolphin		-	-	1 (15)	-
Risso's dolphin	1 (25)	-	-	1 (25)	-
Short-finned pilot whale	3 (25)	1[d]	1 (5)	4 (30)	1[d]
False killer whale	-	-	1 (12)[e]	1 (12)	1[e]
Unidentified dolphin	20 (197) ***17(159)***	180	13 (81)[f] ***9(67)***	33 (278) ***26 (226)***	194
Humpback whale	9 (12)	-	2 (4)	11 (16)	2
Minke whale	1 (1) ***0 (0)***	-	-	1 (1) ***0 (0)***	-
Unidentified toothed whale	1 (4)	-	-	1 (4)	-
Unidentified whale	3 (3)	-	-	3 (3)	-
Total	51 (415) ***46 (361)***	181	30 (1671)[b] ***22(1643)***	81 (2091) ***68 (2004)***	217[c]

[a] Useable detections are those made during or concurrent with useable daylight visual observations; see *List of Acronyms and Abbreviations* for the definition of "useable" observation effort.

[b] One of the matches consisted of one visual sighting with seven corresponding acoustic detections.

[c] Seven of these detections were of the same individual, as confirmed by visual sightings.

[d] There was a possible detection of short-finned pilot whales during an acoustic detection of unidentified dolphins.

[e] Probable false killer whales.

[f] One of these matches consisted of an acoustic detection that corresponded to two different visual sightings (since the vocalizations could not be easily distinguished for the two sightings).

suggest that nighttime monitoring, including use of NVDs, can have some limited success in detecting cetaceans close to the *Ewing* under some nighttime conditions, as described below. The groups discussed below for which power downs were performed are further described in Appendix G, which describes the sightings that triggered power downs and shut downs. Nighttime sighting rates are discussed later.

The first nighttime sighting of dolphins occurred on 28 Nov. at 02:57 GMT with Bf 1. The MMOs were on the flying bridge at night, specifically to observe for sea turtles close to nesting beaches. A group of three unidentified dolphins was sighted swimming parallel to the vessel at a distance of ~30 m, during operations with 3 GI guns. The GI guns were subsequently powered down (Appendix G). The dolphins were initially detected when the observers heard splashing near the bow. A dorsal fin was then spotted off the port bow with the naked eye. The dolphins approached the *Ewing* to within ~5 m to bowride. One observer moved to the lower deck to look over the bow where the dolphins could be seen with the naked eye as well with NVDs. From the flying bridge, the NVDs were not very useful for observing the dolphins, since only the splashes made by the animals could be seen from there. (MMOs on the flying bridge were ~15 m aft of and ~10 m higher than the observer position at the bow.) The dolphins were also heard by PAM.

On 17 Dec. at 03:41 GMT, four pantropical spotted dolphins were sighted at night while 3 GI guns were firing. The dolphins were first sighted using NVDs with Bf 4, after the PAM operator told the MMOs that dolphin whistles were being heard. These dolphins were first seen swimming parallel to the *Ewing* and ~20 m away. They subsequently approached the vessel to within ~5 m to bowride, and a power down was implemented (Appendix G). The dolphins were seen at the bow for ~2 h. Later that night at 08:22 and 09:57 GMT, two groups of unidentified dolphins (two and eight individuals apiece) were first seen with the naked eye as they briefly bowrode ~5 m off the bow. A power down was not undertaken because they were outside the depth-appropriate safety radius, and were last seen heading away from the bow and GI-gun array.

The following night (18 Dec.), another group of four pantropical spotted dolphins was seen by naked eye at 02:49 GMT after the PAM operator alerted the visual MMOs that dolphin whistles were being heard. This sighting occurred in Bf 2 . The group was first seen ~5 m away swimming towards the *Ewing* to bowride during operations with 3 GI guns. A power down was implemented (Appendix G), and the dolphins remained at the bow for ~35 min.

That same night (18 Dec.), at 08:50:34 GMT, a group of three pantropical spotted dolphins was first seen with the naked eye while bowriding ~10 m off the port bow, after the PAM operator cued the visual MMOs that dolphin whistles were being detected by PAM. The three dolphins were then joined by five more dolphins off the starboard bow. They were sighted in Bf 3 when 3 GI guns were firing, and a power down was implemented (Appendix G).

Sightings with GI Guns On.—The majority (62% or 42) of the 68 useable sightings were made while the GI guns were on, whereas 38% were made before the GI guns were deployed or >2 h after they were shut off (Tables ES.1 and 4.1). Similarly, most (84%) of the individual cetaceans were seen while the GI guns were on (Table 4.1). Correspondingly, 78% of the useable effort occurred while the GI guns were on, and 22% was with GI guns silent (Table ES.1). Nearly all (88%) of the 42 useable groups seen while GI guns were on were seen while 3 GI guns were operating; five groups were seen while 2 GI guns were firing during line changes, and the remaining one group was seen when one GI gun was firing. No cetaceans were first seen during ramp-ups.

The GI guns were shut down four times and powered down eight times because of the presence of cetaceans within or near the designated, depth-appropriate safety zones. Two shut downs and a separate power down were done for the same dolphin, and one shut down for humpbacks was preceded by a power down. Further details on these encounters are provided later in this chapter (see *Cetaceans Potentially Exposed to Sounds ≥180 dB*) and in Appendix G. There were numerous additional power downs and shut downs for sea turtles (see Chapter 5)

Sighting/Detection Rates.—Sighting rates (# groups sighted per unit effort) during various types of MMO effort are presented in Table 4.3. Based on the number of useable groups seen per kilometer, the sighting rate was twice as high during non-seismic as during seismic conditions. Based on the number of useable groups seen per hour, the sighting rate was five times as high during non-seismic as during seismic conditions (Table 4.3). However, useable effort was at least 3.5 times higher during seismic compared to non-seismic conditions; non-seismic effort was small. Furthermore, most useable non-seismic effort occurred while in transit to and from the actual survey area (Fig. 4.2), when the ship speed was generally twice as fast as during seismic operations (9–11 kt vs. 4–5 kt). Thus, sighting rates (especially on a "per hour" basis) during seismic vs. non-seismic periods are not a reliable measure of potential effects of seismic. Later in this chapter, sighting rates are further stratified by water depth category and seismic state, and are compared in terms of density (#/km^2). Acoustic detection rates were also 2–5 times higher during non-seismic vs. seismic periods, although the non-seismic acoustic effort was very limited, as discussed later under acoustic results (Table 4.3)

Day-time sighting rates were over four times higher than nighttime sighting rates during seismic periods (Table 4.3); this trend is to be expected given the limited detection range for cetaceans via the NVDs at night. That range is ~150–250 m based on ground-truthing studies with targets, although during this cruise delphinids were seen at night only up to 30 m. There was too little nighttime visual effort during non-seismic periods (Table 4.3) to allow comparisons of nighttime sighting rates between seismic and non-seismic periods.

Daytime sighting rates were similar between "useable" visual effort and all effort (e.g., useable plus non-useable effort; Table 4.3). Sighting rates during daytime non-useable effort have not been specifically investigated , but would be expected to be lower than those during useable effort. That may not have been the case during this cruise.

Other Vessels—The IHA required that MMOs record the number and characteristics of vessels <5 km from any marine mammal sightings (Appendix A). There were numerous vessels of various types near the *Ewing* throughout the study. The most common vessels seen were small fishing boats and cargo/container ships, but one tanker, a sailboat, and at least two private yachts whose occupants were spear fishing for tuna were also seen. Most of these vessels were seen at distances >5 km, although some of the smaller boats approached to within ~100 m of the *Ewing*. Most of the vessels were, when seen, beyond 5 km from any of the cetaceans sighted by the MMOs. The occasions when vessels were seen <5 km from a cetacean are summarized below.

On 22 Nov. at 19:31 GMT, a group of ~600 spinner dolphins was seen ~2 km from the *Ewing* while 3 GI guns were on. The dolphins were swimming around and across the bow of a small sport fishing vessel that was located in the middle of the group. The MMOs were unable to determine whether the boat had approached the dolphins, or whether the dolphins had approached the boat. The MMOs suspected that the vessel had followed the dolphin group to spearfish for tuna. The vessel was stationary while it was in the middle of the dolphin group. At the same time, there was another boat fishing ~2 km away from the dolphins (~4 km away from the *Ewing*). In addition, there was a small private yacht that passed by the *Ewing* at ~500 m, heading away from the dolphins. There was no apparent adverse reaction by the dolphins to any of the vessels.

TABLE 4.3. Encounter rates for acoustic detections and visual sightings from the *Ewing* during the ETPCA seismic survey, 21 Nov.–22 Dec. 2004.

Type of Effort	Seismic					Non-Seismic					Total				
	No. of Detections	Effort (h)	Detection Rate (No./h)	Effort (km)	Detection Rate (No./km)	No. of Detections	Effort (h)	Detection Rate (No./h)	Effort (km)	Detection Rate (No./km)	No. of Detections	Effort (h)	Effort (km)	Detection Rate (No./h)	Detection Rate (No./km)
All Nighttime Visual	6	186	0.03	1537	<0.01	0	1	0.00	8	0.00	6	187	1545	0.03	<0.01
All Daylight Visual	44	320	0.14	2628	0.02	30	34	0.88	624	0.05	74	354	3252	0.21	0.02
All Visual (Day and Night)	50	506	0.10	4165	0.01	30	35	0.86	632	0.05	80	541	4797	0.15	0.02
Useable Visual	42	255	0.16	2124	0.02	26	33	0.79	610	0.04	68	288	2734	0.24	0.02
Useable PAM	77	251	0.31	2087	0.04	4	4	1.00	30	0.13	81	255	2117	0.32	0.04
All PAM (Day & Night)[a]	206	609	0.34	5008	0.04	5	4	1.25	36	0.14	211	614	5044	0.34	0.04
PAM Day[a]	80	301	0.27	2488	0.03	4	4	1.00	32	0.13	84	305	2519	0.28	0.03
PAM Night[a]	126	308	0.41	2521	0.05	1	1	1.00	4	0.25	127	309	2525	0.41	0.05

[a] Useable detections are those made during or concurrent with useable daylight visual observations as defined in *List of Acronyms and Abbreviations*.

[b] The total detections and effort for **seismic+non-seismic** do not equal **total**, because of detections and effort in the **recently** and **potentially exposed** *(i.e., "Post-seismic")* categories that are not included separately in this table. Some other totals may not add up exactly, due to rounding.

On 24 February, two groups of unidentified dolphins were sighted at 22:51 and 23:00 GMT while 3 GI guns were on. The first group was initially seen ~4.6 km from the *Ewing*, but then approached to ~2.4 km. The second group was seen 9 min later at ~2.4 km from the *Ewin*g. There was a cargo vessel ~500 m from the *Ewing* at a relative bearing of 55º. The cargo vessel came as close as ~300 m and crossed the *Ewing*'s path. The dolphins did not appear to show an adverse reaction to the cargo vessel.

On 29 February, at 11:52 GMT, a group of 20 unidentified dolphins were seen 1650 m from the *Ewing* while 3 GI guns were on. A fishing boat was initially seen heading south in the same direction as the dolphins, but ~6 km away from the *Ewing*. Eventually, the dolphins crossed at a distance of ~200 m in front of the fishing boat.

Distribution of Cetaceans

Cetacean sightings in the study area are plotted in Figure 4.2. Acoustic detections of cetaceans are plotted in Figure 4.3 and are discussed in detail later. As noted earlier, vessel-based cetacean surveys have been conducted in the wider ETP for a number of years (e.g., Smith 1983; Hall and Boyer 1989; Polacheck 1987; Wade and Gerrodette 1993; Ferguson and Barlow 2001). However, there is little detailed information about cetacean distribution and abundance in the ETPCA study area per se. Productivity is generally high (>25 $mgC/m^2/day$) in this coastal region (Kobblentz-Mishke et al. 1970 *in* Cushing and Walsh 1976), and the high productivity has been attributed to upwelling at the Costa Rica Dome (Wyrtki 1964; Fiedler et al. 1991; Fiedler 2002). Several studies have correlated zones of high productivity with concentrations of cetaceans (Volkov and Moroz 1977; Reilly and Thayer 1990; Wade and Gerrodette 1993). Several species of dolphins were expected to be relatively common within the study region (see Appendix E.2)

Observations and acoustic detections during the ETPCA study indicate that, as expected, ***dolphins*** were relatively common in the study area, despite the *Ewing*'s ongoing seismic operations with up to 3 GI guns. Not surprisingly, the highest numbers of cetaceans were detected where the most useable effort was concentrated, i.e., within the seismic survey grids (Fig. 1.1, 4.2, 4.3). There were also numerous cetacean detections during useable effort in transits off Costa Rica. The low numbers of cetaceans sighted in the Southern Sandino Basin (SSB), and possibly off central Panama (Fig. 4.2), were probably attributable to the fact that surveys in those areas were during periods with higher Beaufort Wind Force. That presumably decreased sightability of cetaceans. The frequency of sightings in those two areas (SSB and off Panama) was also comparatively low for sea turtles (see Fig. 5.1 in Chapter 5). However, a fair number of dolphins were detected acoustically in the SSB (Fig. 4.3; see *Acoustic Monitoring Results* later). The lower numbers detected in the SSB could also have been related to the fact that *Ewing* seismic operations had been ongoing in the region for nearly three weeks by the time the SSB (Grid 2) was surveyed with the 3 GI guns (Table 2.1). However, most sightings in the area were of dolphins, and there is no evidence of large-scale displacement of dolphins during previous seismic studies. Also, just prior to seismic operations in the SSB, there was a three-day gap in seismic operations in the region. That is likely to have reduced any displacement effect; the *Ewing* was surveying >400 km north in the Gulf of Fonseca prior to operations in the SSB (see Table 2.1 and Fig. 4.1). Thus, it is unlikely that the lower sighting rate in the SSB was related to an avoidance effect.

The most common and widely distributed species were spotted and bottlenose dolphins as summarized above (see Table 4.2 and Fig. 4.2). The three spinner dolphin groups were also widely distributed and represented many more individuals (n = 1350) than any other species (Table 4.2). These results are similar to results of surveys conducted in the general region during July through Dec., although the latter surveys reported higher densities (Ferguson and Barlow 2001; see Appendices E.1, E.2 and H.1).

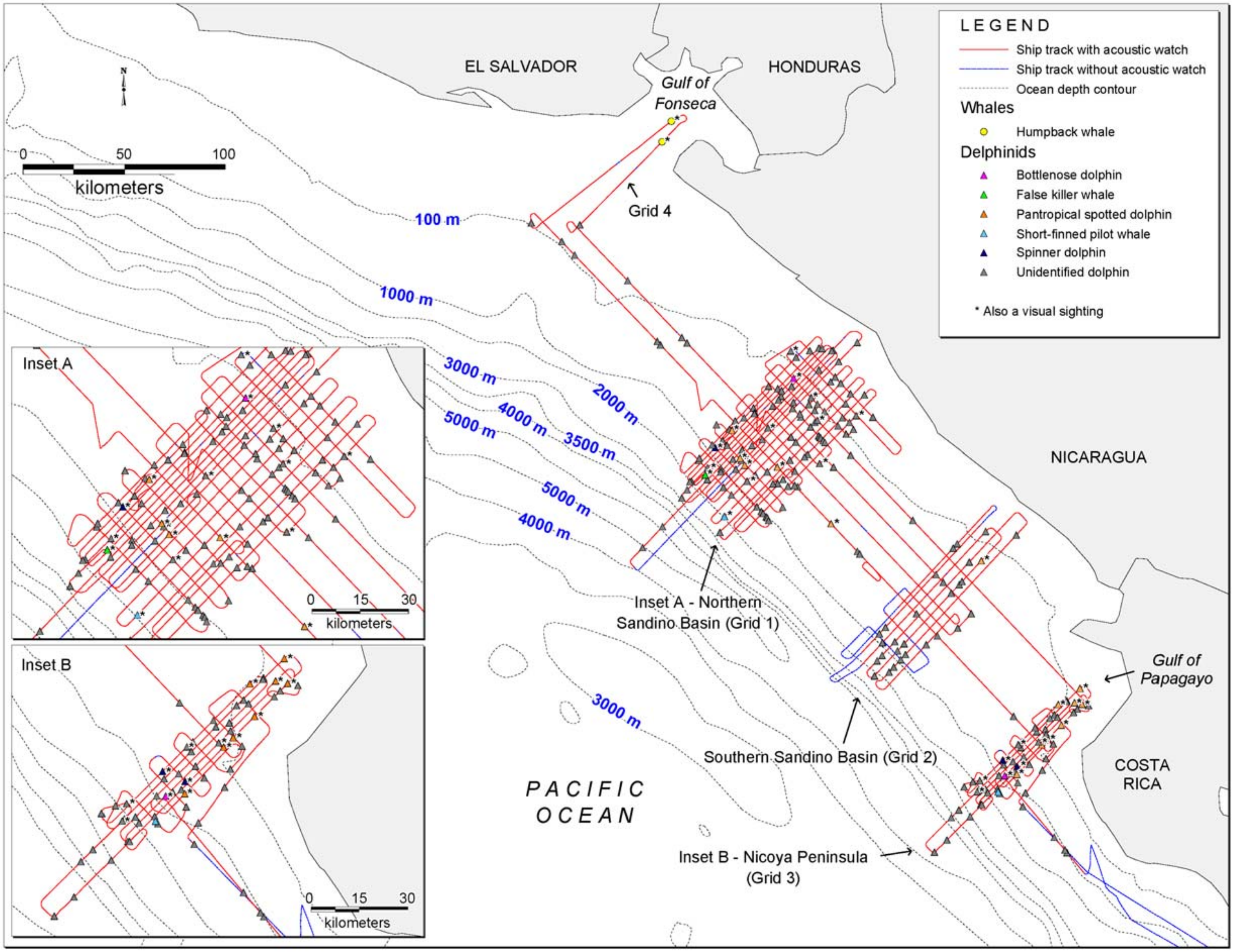

FIGURE 4.3. Locations of all cetacean acoustic detections made during the ETPCA seismic cruise showing periods with and without acoustic monitoring effort, 21 Nov. – 22 Dec. 2004.

However, common dolphins were scarce and striped dolphins were not seen during the ETPCA cruise, but were two of the most commonly reported delphinids during previous surveys (Appendix E). The previous surveys in the region were conducted primarily in late summer/early fall, as compared to late fall for the ETPCA cruise.

A small concentration of ***humpback whales*** (8 groups totaling 12 whales) was seen in the Gulf of Fonseca near the Honduras/El Salvador/Nicaragua borders on 9 Dec. (Fig. 4.2). Two of these individuals were also recorded singing (Fig. 4.3; see *Acoustic Monitoring Results* later and Pavan 2005). To our knowledge, concentrations of humpbacks, including singing humpbacks, have not previously been reported in this specific area (see review in LGL Ltd. 2004a,b). Ferguson and Barlow (2001) found no humpback whales in their 5°×5° survey block 118, which contains the ETPCA survey area, for surveys conducted during July–Dec. Northeastern Pacific humpbacks are known to migrate along this coast to waters as far south as Costa Rica during the northern hemisphere winter (Steiger et al. 1991; Acevedo and Smultea 1995; Rodriguez-Fonseca 2001; Rasmussen et al. 2002). Genetic analyses suggest gene flow (either past or present) between the North and South Pacific (e.g., Baker et al. 1993; Caballero et al. 2001). Various lines of evidence concerning humpbacks sighted off Costa Rica indicate that both northern and southern populations use the area during their respective winters. This observation is based on photo-identification matches and the sighting dates (including those for calves) relative to the calving seasons for northern and southern hemisphere humpbacks (Acevedo and Smultea 1995; Rasmussen et al. 2002; Rodriguez-Fonseca 2001).

A humpback mother-calf pair was seen on 25 Nov. at 10°39.9'N, 85°56.4'W over water depths of ~85 m, ~20 km northeast of the Gulf of Papagayo and the Nicoya Peninsula (Fig. 4.2, Appendix F.3). Rodriguez-Fonseca (2001) identified the Gulf of Papagayo at the southern end of the ETPCA survey area as an important area for humpbacks. During this ETPCA cruise, the sighting date and the size of the calf relative to the mother suggest that the pair may have been from the southern hemisphere population of humpbacks. Northern hemisphere humpbacks winter primarily in Mexican, Hawaiian, and Japanese waters from Dec. to April, and southern hemisphere humpbacks of the eastern Pacific population winter primarily near the equator from June to October (Flórez-González 1991; Acevedo and Smultea 1995). Typically, calves are sighted most frequently toward the end of the humpback wintering season (Chittleborough 1958; Smultea 1994; Craig and Herman 2000; Craig et al. 2003). North Pacific humpback calves are seen off Hawaii between mid-Dec. and early May, and peak in late February–early March (Smultea 1994; Craig et al. 2003). Mid-to-late Nov. would be an unusually early sighting for a northern hemisphere humpback calf, but would not be atypical for a southern hemisphere calf. Furthermore, the calf was judged to be about one-third the length of the mother, which is the typical size of a humpback calf when a few months old (Reeves et al. 2002). Rasmussen et al. (2002) matched February–March humpback sightings off northwestern Costa Rica with a northern hemisphere humpback population based on photo-identification.

The survey effort was insufficient to allow valid quantitative comparisons of cetacean distribution and numbers in relation to water depth. However, density trends relative to water depth are discussed later in this chapter, incorporating correction factors for effort and sightability.

Some of the sightings in the ETPCA study area may have been repeat sightings of the same cetaceans, especially where survey lines were spaced closely together. In particular, a single pantropical spotted dolphin was sighted repeatedly over a period of ~26 h apparently following the *Ewing* while the GI guns were both on and off. One power down and two shut downs were required for this individual when it closely approached the *Ewing* and its operating GI guns (see below and Appendix F.5).

Marine Mammal Behavior

Three types of data collected during visual observations with and without GI gun operations provide information about behavioral responses to the seismic survey: estimated closest observed point of approach to the array, movement relative to the vessel/array, and behavior observed.

Closest Observed Point of Approach

On average, delphinid groups were seen an average of ~170 m closer to the GI guns when the GI guns were off vs. on (741 m vs. 909 m; n = 28 vs. 25 groups; Table 4.4). For whales, the difference was larger (92 m vs. 1250 m), but only one group (of four unidentified whales) was seen during non-seismic conditions vs. 14 groups during seismic operations (Table 4.4). The standard deviations were large for both delphinids and whales (Table 4.4). Furthermore, the sample sizes were insufficient to consider the effects of the various GI-gun array volumes, without or with separate consideration of the three water depth strata. A wide range of received sound levels can occur at a given distance depending on the water depth and the array and gun volume in use at the time, as discussed later in this chapter and in Appendix B.

These limited results are consistent with the possibility that the small seismic sources had a slight displacement effect on cetacean distribution immediately around the *Ewing*. Indications of such an effect have been found during prior *Ewing* seismic surveys with both larger arrays (e.g., 20 airguns) and small arrays of ≤6 airguns or GI guns (Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005).

However, three cetacean groups (one spotted dolphin and two humpback groups) approached the operating GI guns to CPA distances (67–218 m) where estimated sound levels were >180 dB. Estimated numbers of cetaceans exposed to various sound levels are further discussed later in this chapter.

Categories of Behavior

Cetacean behavior is difficult to observe. Cetaceans are often at the surface only briefly, and there are difficulties in resighting individuals or groups, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Limited behavioral data were collected during this project because cetaceans were often seen at a distance from the vessel, and they were typically not tracked for long distances or times while the vessel was underway. However, one pantropical dolphin was seen and heard calling on numerous occasions over a period of ~26 h as described below. The two parameters that were examined quantitatively to assess potential seismic effects on cetacean behavior were the first behavior and first movement observed (see Appendix B for variables and definitions). The CPA recorded for each group sighting, as described above and in Appendix D, was also an indicator of behavior.

Sample sizes within this one cruise were too small to permit species-specific comparisons between seismic vs. non-seismic periods. Thus, species were combined into delphinids (n = 53) and whales (n = 15).

First Observed Movement.—Based on the relatively small sample sizes available, the first observed movement was variable. For delphinid groups, the predominant first movement during both non-seismic periods (n = 25 groups) and seismic periods (n = 28) groups was swimming parallel to the *Ewing*'s course (36% vs. 39% of sightings; Table 4.5). Milling was more common for delphinids seen during non-seismic than seismic periods (26% vs. 8%). During seismic periods, swimming away or swimming toward the *Ewing* (25% and 21%, respectively) was more common than during non-seismic periods (12% each).

TABLE 4.4. Closest observed points of approach (CPA) of delphinids and whales to the GI guns relative to estimated maximum received sound level (dB re 1 μPa, rms), considering sightings during useable[a] non-seismic and seismic periods during the ETPCA cruise, 21 Nov.–22 Dec. 2004.[b]

		Seismic					Non-seismic			
Species Group	**No. of Groups**	**Estimated Received Level at CPA to GI Guns**	**Mean CPA (m)**	**SD**	***n***	**Range (m)**	**Mean CPA (m)**	**SD**	***n***	**Range (m)**
Delphinids										
	48	≤160 dB	1083	860	23	218-3238	741	731	25	87-3075
	5	>160 dB	111	61	5	67-218	-	-	-	-
Total	53	All	909	864	28	67-3238	741	731	25	87-3075
Whales										
	10	≤160 dB	1701	1490	9	458-4708	92	-	1	92
	5	>160 dB	437	396	5	89-996	-	-	-	-
Total	15	All	1250	597	14	89-4708	92	-	1	92

[a] Useable detections are those made during useable daylight visual observations as defined in *List of Acronyms and Abbreviations*.

[b] An additional 15 non-useable groups of cetaceans were seen within the 160 dB radii during the ETPCA cruise. The total numbers of cetaceans seen or estimated to have been in areas with received sound levels >160 dB are discussed later under *Number of Marine Mammals Present and Potentially Affected*.

It was not possible to compare whale movement during seismic vs. non-seismic periods because only one whale was seen (swimming toward the *Ewing*) while the GI guns were off (Table 4.5). During seismic periods, movement was variable for the 14 whale groups that were seen, although nearly half (43%) swam away from the *Ewing* while the GI guns were on (Table 4.5).

First Observed Behavior.—Most (72%) of the 25 delphinid groups seen during non-seismic periods were swimming/traveling when first seen (Table 4.6). During seismic periods, the first observed behavior of the 28 delphinid groups was more variable; the most common behaviors were porpoising (32%), swimming/traveling (29%), and breaching/tail lobbing (25%). Porpoising (rapid travel with leaping above the water surface) was seen 8 times more frequently during seismic than in non-seismic periods; breaching/tail lobbing was seen twice as frequently during seismic periods (Table 4.6). Feeding behavior was noted twice during seismic and twice during non-seismic periods. The one delphinid group that was bowriding when first observed was seen while the GI guns were off.

For whales, it was not possible to compare the first-observed behavior during seismic vs. non-seismic periods because only one whale was seen (traveling/swimming) while the GI guns were off. For the 14 whales seen during seismic periods, the first observed behavior was predominantly blowing (64%) followed by swimming/traveling (29%) or diving/fluking up (7%) (Table 4.6).

TABLE 4.5. Comparison of first observed direction of movement by delphinids and whales seen during non-seismic and seismic periods during the ETPCA seismic cruise, 21 Nov.–22 Dec. 2004. Only useable[a] sightings are included. Sightings 90 s to 2 h after the GI guns ceased operating are excluded from both "non-seismic" and "seismic" categories, as described in Chapter 3 *Analyses*. See Appendix D for descriptions of behavior categories.

	First Observed Movement						
Species	**Mill**	**Swim Perpen-dicular**	**Swim Away**	**Swim Parallel**	**Swim Toward**	**None/ Unknown**	**Total**
Delphinids							
Non- seismic	7	2	3	9	3	1	**25**
Seismic	2	0	7	11	6	2	**28**
Whales[b]							
Non-seismic	0	0	0	0	1	0	**1**
Seismic	0	0	6	4	2	2	**14**
Subtotal							
Non- seismic	**7**	**2**	**3**	**9**	**4**	**1**	**26**
Seismic	**2**	**0**	**13**	**15**	**8**	**4**	**42**
Grand Total	**9**	**2**	**16**	**24**	**12**	**5**	**8**

[a] Useable detections are those made during useable daylight visual observations as defined in *List of Acronyms and Abbreviations*.

[b] Whales includes 11 humpback and 4 unidentified whale groups.

Overall, based on all behaviors recorded (not just initial behavior), 9 of the 65 delphinid groups observed during all conditions exhibited bowriding: seven during seismic and two during non-seismic periods. The two groups of dolphins seen bowriding during non-seismic periods were bottlenose dolphins. Three GI guns with a total volume of 135 in^3 were operating during all seven of the seismic sightings, which included three groups of pantropical spotted dolphins, three groups of unidentified dolphins, and one group of bottlenose dolphins. While at the surface off the *Ewing*'s bow, all seven of these groups were outside the safety radius for the 3-GI-gun array given the water depth at the time. Nonetheless, a power down was performed for five of the seven bowriding episodes during seismic periods (see below).

As noted above, a lone pantropical spotted dolphin was sighted repeatedly near the *Ewing* for over 26 h on 23–24 Nov. while the GI guns were both on and off. This dolphin was seen in the Gulf of Papagayo off the Nicoya Peninsula, northwestern Costa Rica (Fig. 4.2). The dolphin was recognized by unique physical characteristics seen and noted by the MMOs. In general, the animal's behavior was variable. A summary of the dolphin's behavior, including vocal behavior, along with a chronological description of this encounter, is provided in Appendix F.5.

TABLE 4.6. Comparison of initially observed behavior of cetacean groups during non-seismic and seismic periods during the ETPCA seismic cruise, 21 Nov.–22 Dec. 2004. Only useable[a] sightings are included. Sightings 90 s to 2 h after the GI guns were firing are excluded from both "non-seismic" and "seismic" categories. "Non-seismic" includes sightings before or >2 h after GI guns were on, as described in Chapter 3, *Analyses*. See Appendix D for descriptions of behavior categories.

Species	Blow	Bow-ride	Breach/ Tail Lob	Dive/ Fluke up	Feed	Porp.	Swim /Trav.	Unkn.	Total
Delphinids									
Non-seismic	**0**	1	3	0	2	1	18	0	**25**
Seismic	**0**	0	7	1	2	9	8	1	**28**
Whales [b]									
Non-seismic	**0**	0	0	0	0	0	1	0	**1**
Seismic	9	0	0	1	0	0	4	0	**14**
Total									
Non-seismic	0	1	3	0	2	1	22	0	**26**
Seismic	9	0	7	2	1	9	12	1	**42**
Grand Total	**9**	**1**	**10**	**4**	**3**	**10**	**31**	**1**	**68**

[a] Useable detections are those made during useable daylight visual observations as defined in *List of Acronyms and Abbreviations*.

[b] Whales includes 11 humpback and 4 unidentified whale groups.

Acoustic Monitoring Results

Passive Acoustic Monitoring Effort

Passive Acoustic Monitoring (PAM)was conducted for a total of 5200 km (632 h) during the study period (Table ES.1 and Appendix F.6). Of this distance, ~41% coincided with useable daylight visual effort (as defined earlier); the remaining 59% occurred at night or during "non-useable" daylight periods (e.g., Bf >5). PAM occurred during nearly 100% of the time that airguns were operating. However, some (2%) of this PAM effort consisted of unattended recordings when PAM operators were needed on visual watch for sea turtles near important nesting beaches (see Chapters 3, 5). Details of PAM effort, partitioned by number of operating GI guns, are provided in Appendix F.6. Total PAM effort was similar during daytime and nighttime (Table ES.1).

Acoustic Detections

A total of 217 acoustic detections were made in the ETPCA and the mean acoustic encounter duration was 0.5 h (SD = 0.7; Table ES.1). Most (97% or 210) of the 217 acoustic detections were "attended recordings" recorded manually by an MMO on watch during the day or night; the remaining 3% or 7 detections were via "unattended recordings" recorded automatically at night. Those seven detections via unattended recordings at night, as well as an additional 187 detections, were unidentified dolphins. Of the other 23 detections, 14 were of pantropical spotted dolphins, 3 were of spinner dolphins, 2 were of bottlenose dolphins, 2 were of humpback whales, 1 was of short-finned pilot whales, and 1 was possibly of false killer whales (Table 4.2). There may have been additional vocalizations of short-finned pilot whales during a detection of unidentified dolphins, but this is uncertain (Table 4.2).

In 30 cases, the acoustic detection could be matched with a visual sighting, and in 17 of those 30 cases, the species was successfully identified (Table 4.2). All of the acoustic detections that were identified were identified using visual sightings; none were identified by acoustic recognition alone. When acoustic and visual detections could be matched, the animals were detected first acoustically 59% of the time (18 of 30 cases).

Within the ETPCA, the total number of acoustic detections (n = 217) was about three times higher than the number of useable visual sightings (n = 68). However, total PAM effort was about twice that of useable visual effort (5200 km of day and night PAM vs. 2734 km of useable daytime visual effort; Table ES.1). The resulting mean acoustic encounter rate within the ETPCA (day & night) was 0.04 acoustic detections/km. The resulting visual detection rate based on useable observer effort was about half as frequent at 0.02 sightings/km (Table 4.3). The total number of acoustic detections (217) was about 2.7 times higher than the total number of visual sightings, useable and non-useable (n = 81).

A more meaningful comparison may be made by comparing PAM effort that was concurrent with useable visual effort (i.e., daylight only). This comparison indicated that the mean acoustic detection rate was still twice as high as the visual detection rate (0.04 vs. 0.02/km; Table 4.3).

Only 5 of the total 217 acoustic detections were made while the GI guns were not operating. However, PAM effort was extremely limited during "no seismic" periods (4 h; Table ES.1). In comparison, there were 609 h of PAM effort during "seismic" conditions (Table ES.1). This difference in effort occurred because deployment and retrieval of the SEAMAP hydrophone array usually occurred coincident with deployment and recovery of the GI guns. Notwithstanding the limited PAM effort in non-seismic conditions, mean acoustic encounter rates were much lower during seismic than during non-seismic periods (Table 4.3). On average, acoustic detection rates were lower during the day than at night (Table 4.3).

One acoustic detection of unidentified dolphins made on 29 Nov. had two visual sightings associated with it. Subsequent to detecting these dolphins acoustically, a group of 20 unidentified dolphins (possibly pantropical spotted dolphins) were seen ~1427 m away. Then, 24 min later, a single unidentified dolphin was seen 389 m away. Delphinid calls were heard during and between the two visual detections.

Although most acoustic detections could not be linked to individuals, there were seven acoustic detections of a specific lone pantropical spotted dolphin over the course of a ~26-h period, as confirmed by visual sightings of the same identifiable individual described above. The acoustic behavior of this dolphin is described in Appendix F.5.

Discussion

Most acoustic signals that were recorded originated from dolphins, and were whistles in the frequency range of 8 to 20 kHz. Periodically, lower-frequency whistles were also detected. On one occasion, these whistles were associated with a sighting of short-finned pilot whales. Clicks and click trains were heard only on 36 occasions when dolphins were believed to have approached to within ~200 m of the ship.

All of the acoustic contacts that were identified to species were identified by sight; none of the dolphin calls were identified to species by the acoustic signal alone. However, two acoustic detections of singing humpback whales were made and coincided with visual sightings; these sightings were described above under *Distribution of Cetaceans*. No other species of large whales (e.g., blue or fin whales) were detected acoustically or visually in the ETPCA, even though they are known to occur there at times, and have been detected acoustically in the ETP (e.g., Stafford et al. 1999a,b).

During the ETPCA survey, both acoustic and visual detection rates were 2–5 times higher during non-seismic than during seismic periods. This result from a cruise in late 2004 is similar to results during previous *Ewing* seismic cruises conducted earlier in 2004 (Smultea et al. 2004, 2005). The overall results from those cruises suggest that the seismic sounds may have caused delphinid call rates and the numbers of (visible) cetaceans within the respective monitored areas to decrease. Dolphins in the ETP, in particular, are more prone to flee from large vessels than are other populations of dolphins, presumably because ETP dolphins have been chased for decades and caught in purse seines associated with the tuna fishing industry (Allen 1985; Hall and Boyer 1989; Wade 1995; Hall 1997). It is possible that they may be more sensitive to seismic sounds as well. Acoustic detection rates were also 2–8 times higher than visual sighting rates (Table 4.3). This is typical for joint visual/acoustic surveys (Thomas et al. 1986; Fristrup and Clark 1997; Barlow and Taylor 1998; Norris et al. 1999), including two prior *Ewing* seismic cruises when both PAM and visual monitoring were conducted (Smultea et al. 2004, 2005). Acoustic detection rates during the ETPCA cruise were also about twice as high during nighttime as during daytime; again, this trend has been reported elsewhere (e.g., Stienessen 1998), including during the two previous *Ewing* seismic cruises noted above.

Seasonal, geographic, and diurnal differences are known to affect acoustic detection rates at times (e.g., Stafford et al. 1998, 1999b; Stienessen 1998; Moore et al. 1999). However, factors affecting the acoustic behaviors of cetaceans are generally not well understood, and this complicates the use of PAM and interpretation of PAM results. Variability in vocalization rates and call intensity can dramatically affect detection rates of animals during surveys. In addition, these factors are potentially confounded due to the presence of the *Ewing* and its associated seismic activity. Results of recent studies on a variety of species indicate that vessel and airgun noise may or may not influence sound production rates in cetaceans. Other factors, such as habituation and novelty of the anthropogenic sounds, may also affect acoustic behaviors of cetaceans.

It is evident from the ETPCA results (and some previous studies) that at least some cetaceans call in the presence of airgun pulses. However, because PAM effort in the absence of seismic operations was so limited during this cruise, it was not possible to assess whether acoustic detection rates were significantly different during seismic vs. non-seismic periods. For example, it is possible that animals exposed to airguns decreased their sound production rate or intensity, or perhaps (in some cases) avoided the *Ewing*. In addition, issues related to vessel noise (e.g., masking) may have affected detection of cetacean sounds. Elucidation of these issues will require additional investigation of the effects of airgun and vessel noise on call detection rates, and more generally on the normal acoustic behavior of marine mammals.

In most circumstances, complementing visual observations with PAM is effective for increasing rates of detections for many species of cetaceans. It is particularly advantageous to conduct PAM at night, when visual monitoring is not very effective. For example, during the ETPCA survey, three sightings of spotted dolphins were initially detected acoustically at night and subsequently visually with NVDs, and a power-down was implemented after subsequent visual confirmation of the groups.

However, due to the difficulties in identifying calls to species level, and in localizing the source of the calls, acoustic monitoring still is most effective when coupled with visual surveys. When species identification is not a critical component (e.g., for mitigation), then acoustic monitoring without visual confirmation may be acceptable, depending on whether distance of the animal(s) relative to the noise source can be determined with acceptable accuracy. Determination of distance from PAM alone is possible, but has been impractical with the system as deployed from the *Ewing* to date. Nighttime and times with poor sighting conditions are situations in which PAM can greatly enhance the ability to detect the presence of calling cetaceans. For example, visual detection rates of both cetaceans and sea turtles in the Southern Sandino Basin were very low, presumably related to the poor and non-useable (Bf ≥5) observation conditions; however, the number of acoustic detections remained relatively high, as discussed for *Distribution* above (also see Fig. 4.2). Nevertheless, proper acoustic monitoring protocols must be used. Furthermore, because the hardware and software systems used for PAM and mitigation are relatively new, refinements and improvements are required. There are some simple improvements that can be implemented without significant costs.

Mitigation Measures Implemented

During this cruise, the GI guns were fully shut down on four occasions because cetaceans were seen in the safety zone, and on eight occasions a power down was implemented (Table 4.7; Appendix G). Both a power down and a subsequent shut down (without resumption of operations in between) were implemented for a humpback whale sighting. Also, two shut downs and a power down occurred on three separate occasions for the same individual pantropical spotted dolphin described above (see Appendix F.5). The fourth shut down occurred for a humpback whale. The remaining power downs were implemented for a bottlenose dolphin, unidentified dolphin, humpback whale, and three pantropical spotted dolphin sightings. All power/shut downs occurred while the smaller GI gun array (135 in^3) was in use. At the times of most of these power/shut downs, 3 GI guns were firing, but on two occasions, only 2 GI guns were firing. Five of the power/shut downs occurred in shallow (<100 m) water where the 180 dB safety radius was 433 m, and six occurred in intermediate (100–1000 m) water, where the safety radius was 93 m (Table 3.1).

All power/shut downs were attributable to cetaceans that were first observed in the safety zone. However, only one or a few shots might have been fired while the cetaceans were within that zone. Some of the cetaceans were probably exposed to received levels ≥180 dB re 1 µPa (rms) before the GI guns were powered/shut down. However, most were not exposed to such high levels because the animals were at or close to the surface, and when there would receive lower levels than occur at deeper depths (Greene and Richardson 1988; Tolstoy et al. 2004). The numbers of marine mammals exposed to received levels ≥180 dB re 1 µPa (rms) are estimated in the next section.

Ramp ups were conducted whenever the GI guns were started up after a prolonged period of inactivity. No ramp ups from a shut down were performed at night.

Estimated Number of Marine Mammals Potentially Affected

It is difficult to obtain meaningful estimates of "take by harassment" for several reasons: ***(1)*** The relationship between numbers of marine mammals that are observed and the number actually present is uncertain. ***(2)*** The most appropriate criteria for "take by harassment" are uncertain and presumably variable among species and situations. ***(3)*** The distance to which a received sound level exceeds a specific criterion such as 190 dB, 180 dB, 170 dB, or 160 dB re 1 µPa (rms) is variable. It depends on water depth, airgun depth, and aspect for directional sources (Greene 1997; Greene et. al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Tolstoy et al. 2004a,b). ***(4)*** The sounds received by marine mammals vary depending on their depth in the water, and will be considerably reduced for animals at or near the surface (Greene and Richardson 1988; Tolstoy et al. 2004a,b). ***(5)*** In this project, the use of a variety of airgun configurations at different times also contributed to variability in received levels at any given distance from the source.

TABLE 4.7. List of power downs (PD) and shut downs (SZ) of the GI guns implemented for cetaceans sighted in or near the safety radii during the ETPCA seismic cruise, 21 Nov.–22 Dec. 2004. Some of these PD and SZ were conducted for the same individual(s) as had triggered an earlier PD or SZ.

Species	Group size	Date (2004)	Water depth (m)	Initial sighting distance to MMO	Move-ment[a]	Dove? (yes/ no)	No. of GI guns on prior to SZ or PD	Total GI gun volume prior to SZ or PD (in ^{3})	Estimated 180-dB radius	CPA (m) to operating GI guns before mitigation	Mitigation measure taken (PD or SZ)	Estimated maximum received sound exposure (dB)	No. indiv. exposed to >180 dB re 1 μPa (rms)[b]	Likelihood of exposures to ≥180 dB
Pantropical spotted dolphin[c]	1	23-Nov	76	30	SP	No	2	90	433[f]	30	SZ	>190	1	definite
Pantropical spotted dolphin[c]	1	24-Nov	96	80	SP	No	3	135	433	80	SZ	>190	1	definite
Pantropical spotted dolphin[c]	1	24-Nov	389	50	SP	No	3	135	93	50	PD	<180	0	unlikely
Bottlenose dolphin	15	25-Nov	985	200	ST	No	3	135	93	110	PD	<180	0	unlikely
Humpback whale[d]	2	25-Nov	85	654	SA	No	3	135	433	450[g]	PD	<180	0	unlikely
Unidentified dolphin	3	28-Nov	109	30	SP	No	3	135	93	110	PD	<180	0	unlikely
Humpback whale[e]	1	9-Dec	29	3151	SA	No	3	135	433	450	PD	<180	1	unlikely
Humpback whale[e]	1	9-Dec	29	20	SA	No	3	135	433	91	SZ	>190	1	definite
Humpback whale	1	9-Dec	28	60	SP	No	2	90	433[f]	123	SZ	>190	1	definite
Pantropical spotted dolphin	4	17-Dec	367	20	SP	No	3	135	93	110	PD	<180	0	unlikely
Pantropical spotted dolphin	4	18-Dec	802	5	ST	No	3	135	39	110	PD	<180	0	unlikely
Pantropical spotted dolphin	8	18-Dec	262	10	SP	No	3	135	93	110	PD	<180	0	unlikely

[a] Initial movement of group relative to the vessel: ST = swimming toward, SP = swimming parallel, SA = swimming away.

[b] Number of individuals that came within estimated 180 dB radius for the number and volume of GI guns in use at the time (see text for details).

[c] The same individual prompted two shut downs and one power down.

[d] Probable mother-calf pair.

[e] These whales were in the same group.

[f] Actual distance was smaller (302 m) because only 2 GI guns were operating.

[g] The whales were seen ~200 m from the 1 operating GI gun after the power down was implemented.

Disturbance Criteria

Any cetacean that might have been exposed to GI gun pulses with received sound levels ≥160 dB re 1 μPa (rms) was, in one set of calculations that follow, assumed to have been potentially disturbed. Such disturbance was authorized by the IHA issued to L-DEO. However, the 160 dB criterion was developed by NMFS from studies of baleen whale reactions to seismic pulses (Richardson et al. 1995). That criterion likely is not appropriate for delphinids or pinnipeds: the hearing of small odontocetes is relatively insensitive to low frequencies, and behavioral reactions of small odontocetes and pinnipeds to airgun sounds indicate that they are less responsive than are some baleen whales (Richardson et al. 1995; Gordon et al. 2004; LGL Ltd. 2004a,b). Probable exposure to received levels ≥170 dB was used as an alternative criterion in estimating potential disturbance of delphinids.

Table 4.8 shows the estimated radii at which four specified sound levels would be received from the different GI gun configurations used during the survey. The predicted 160 and 170 dB radii (disturbance criteria for marine mammals) are based on modeling and limited acoustic measurements in deep and shallow waters of the Gulf of Mexico (Table 4.8; Tolstoy et al. 2004a,b). For deep water, the distances quoted are believed to be precautionary (i.e., larger than actual 160 and 170 dB distances).

Safety Radii

During the present project, NMFS required that mitigation measures be applied to avoid or minimize the exposure of sea turtles, cetaceans, and pinnipeds to impulse sounds with received levels ≥170, ≥180, and ≥190 dB re 1 μPa (rms), respectively. No pinnipeds were seen, so only the 170 and 180 dB criteria were actually applied, with only the 180 dB criterion being relevant in this chapter. The safety radii used during the ETPCA study were presented in Table 3.1. The safety radii implemented as power down and shut down distances for cetaceans during the ETPCA cruise (Table 3.1) were often larger than the actual best estimates of the 180 dB distances based on calibration data. This was partly a result of the precautionary nature of the safety radii, at least for deep water, and partly a result of the fact that the safety radii that were applied (Table 3.1) were sometimes those applicable to airgun configurations larger than the one in use. Table 4.8 provides specific estimates of 180 dB (and other) radii for each of the individual configurations. The values in Table 4.8 were the ones used to estimate numbers of cetaceans exposed to various received sound levels.

This section applies several methods to estimate the number of marine mammals exposed to seismic sound levels strong enough that they might have caused disturbance or other effects. The procedures include ***(A)*** minimum estimates based on direct observations, ***(B)*** estimates based on marine mammal densities obtained in the study area via visual observations from the *Ewing* during periods unaffected by seismic surveys, and ***(C)*** estimates based on densities obtained by observers aboard the *Ewing* while it was conducting seismic surveys in the study area. It is likely that the actual number of individual marine mammals exposed to, and potentially affected by, seismic survey sounds was between the minimum and maximum estimates provided below. The estimates provided here are based on observations during this project. In contrast, the estimates provided in the IHA Application and EA for this project (LGL Ltd. 2004a,b) were based on survey and other information available prior to this project.

Estimates from Direct Observations

The number of cetaceans observed close to the *Ewing* during the ETPCA seismic survey provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals likely moved away before coming within visual

TABLE 4.8. Estimated distances (m) to which sound levels ≥190, 180, 170, and 160 dB re 1 µPa (rms) might be received from 1–3 GI guns each with volume 45 in^3 or 105 in^3 operating in various water depths. The estimates are based on acoustic modeling and (for shallow water) empirical data from Tolstoy et al. (2004a,b), adjusted to allow for the varying source levels.

GI guns	Estimated Distance (m) to Radii			
Water Depth	190 dB	180 dB	170 dB	160 dB
Single 45 in^3 GI gun				
Deep (>1000 m)	8	20	68	207
Intermediate (100 - 1000 m)	11	31	102	311
Shallow (<100 m)	94	151	283	566
Single 105 in^3 GI gun				
Deep (>1000 m)	10	27	90	275
Intermediate (100 - 1000 m)	15	41	135	413
Shallow (<100 m)	125	200	375	750
Two 45 in^3 GI guns				
Deep (>1000 m)	13	41	132	385
Intermediate (100 - 1000 m)	19	61	198	577
Shallow (<100 m)	189	302	566	1,131
Two 105 in^3 GI guns				
Deep (>1000 m)	17	54	175	510
Intermediate (100 - 1000 m)	26	81	263	765
Shallow (<100 m)	250	400	750	1,500
Three 45 in^3 GI guns				
Deep (>1000 m)	20	62	200	621
Intermediate (100 - 1000 m)	29	93	300	931
Shallow (<100 m)	294	433	999	1,862
Three 105 in^3 GI guns				
Deep (>1000 m)	26	82	265	823
Intermediate (100 - 1000 m)	39	123	398	1,235
Shallow (<100 m)	390	574	1,325	2,469

range, and not all of those that remained would have been seen by observers during the daytime, let alone at night. It is assumed that no pinnipeds were affected by seismic sounds, as no pinnipeds were seen during the ETPCA cruise.

Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 µPa (rms).—During this project, 12 cetacean groups involving ~39 different individual cetaceans were sighted within or near the safety radius around the GI guns; a power down or shut down was undertaken for all 12 of these occasions (Table 4.7 and Appendix G). Of the 12 power downs or shut downs, five were conducted for the same two groups of cetaceans. One of these "groups" was a single pantropical spotted dolphin: two shutdowns and one power down were done for this animal (Table 4.7). The second group was a single humpback for which a shutdown was preceded by a power down.

The actual 180 dB radius was probably substantially less than the safety radius on 8 of these 12 occasions. There were several reasons for this:

- the cetaceans were at or near the water surface, where the received sound level would be considerably less;
- the animals were near but not within the safety radius;
- the estimated 180-dB radius was smaller than the nominal safety radius (see Appendix G).

Four of the aforementioned 12 shut downs or power downs, involving one pantropical spotted dolphin and two different humpback whales, very likely involved exposure to sounds ≥180 dB as follows. (1) An individual pantropical spotted dolphin was likely exposed twice to sounds with received levels ≥180 dB. This individual was following the vessel, and was intermittently seen near the vessel and the GI guns over the course of ~26 h (see Table 4.7; Appendices F.5 and G). (2) On another occasion, two humpback whales were sighted in shallow water, one of which came within ~90 m of the one GI gun operating after a power down, close enough such that it was likely exposed to sounds ≥180 dB. (3) The third animal that was very likely exposed to received sound levels ≥180 dB was a humpback whale seen ~123 m away from the 2 GI guns operating in shallow water (Table 4.7; Appendix G).

The estimated 180-dB radii shown in Table 4.8 are the maximum distances from the array where sound levels were expected to be ≥180 dB re 1 μPa (rms). In deep (>1000 m) water, this maximum distance is likely ~40–50 m below the water surface when near the bow of the *Ewing*. At the water surface near the bow of the *Ewing*, these estimated received sound levels are considerably reduced because of pressure-release effects. In many cases, it is unknown whether animals seen at the surface were earlier (or later) exposed to the maximum levels that they would receive if they dove deeply. Thus, there are complications in assessing the maximum level to which any specific individual mammal might have been exposed. However, for bowriding dolphins observed at or near the surface for extended periods, the received GI gun sounds would remain reduced relative to levels at deeper depths. Other considerations include the following:

- Some cetaceans may have been within the predicted 180 dB radii and/or within the safety radii while underwater and not visible to observers, and subsequently seen outside these radii. The direction of movement as noted by MMOs can give some indication of this.
- The MMO station on the flying bridge was ~94 m forward of the GI guns in their normal configuration, and the tip of the *Ewing*'s bow was ~109 away from the nearest GI gun. Therefore, the nominal safety zone was not centered around the observer's station, but rather around the center of the airgun array. This difference was accounted for in the observer's decisions regarding whether it was necessary to shut down the GI guns for sightings immediately forward or astern.
- Because the 3 GI guns were aligned in the cross-track direction, their sounds were stronger in the fore-aft direction than in the cross-track direction. However, we have assumed that the 180 dB distance was as far to the side as it was fore and aft.

Cetaceans Potentially Exposed to Sounds ≥160 dB re 1 μPa (rms).—A total of 81 groups of cetaceans were sighted during the ETPCA cruise. Of the 16 groups that were not identified as delphinids, 14 were sighted when the GI guns were operational (Appendices F.3 and F.4). These included 3 single unidentified baleen whales, and 11 groups of 16 humpback whales. One humpback whale (described above) was seen while 2 GI guns were firing, but the other 13 whale groups were seen while all 3 GI guns were in operation. Seven of the 14 groups (10 different individuals) seen during seismic operations were believed to be unique groups that entered the ≥160 dB radius (see Appendix F.3 for sightings). Thus, two unidentified baleen whales and eight different humpback whales are considered to have been potentially disturbed by seismic sounds based on the "direct observation" method. One of these groups included a mother-calf pair (see Appendix G). Given that about one-half of the seismic surveys were done at night, it is possible that a small number of additional unseen baleen whales might have been exposed to ≥160 dB at night.

Of the total 65 groups of delphinids seen during the cruise (useable and unuseable), 36 groups were sighted while the GI guns were operational. Most of those groups (26) were seen when all 3 GI guns were operating. The majority of sightings (26) occurred in intermediate water, 8 occurred in deep water, and 2 were in shallow water. In total, 25 delphinid groups involving 238 individuals were detected within the ≥160 dB radii around the operating GI guns. These include the animals that caused power and shut downs discussed in the section above. Although three of those groups were detected at night, some additional delphinids were probably present within the ≥160 dB zone during nighttime seismic operations. However, many delphinids exposed to received levels of ~160–170 dB re 1 µPa (rms) may not have been disturbed significantly.

Delphinids Potentially Exposed to Sounds ≥170 dB re 1 µPa (rms).—For delphinids, exposure to GI gun sounds with received levels ≥170 dB may be a more appropriate criterion of disturbance than exposure to ≥160 dB. The delphinid hearing system is less sensitive to low-frequency sounds than is the auditory system of large whales (at least baleen whales). Of 65 groups of delphinids observed from the *Ewing*, 36 were seen during seismic operations. A total of 11 delphinid groups involving 88 individuals were seen where received levels of GI gun sounds were estimated to be ≥170 dB radii (including the animals for which power downs were implemented). Additional delphinids were probably present within the ≥170 dB zone during nighttime seismic operations.

Estimates Extrapolated from Marine Mammal Density

The number of marine mammals sighted during the ETPCA survey (even after allowance for the portion of the seismic survey conducted at night) presumably underestimates the actual number present during the survey because some animals present near the tracklines were not seen by the observers. Animals present near the tracklines during daylight would not be seen by the observers if the animals were below the surface when the ship was nearby. Some others, even though they surfaced near the vessel, would be missed because of limited visibility, high Beaufort Wind Force, glare, or other factors limiting sightability. Furthermore, some animals would be expected to avoid the area near the seismic vessel while the GI guns were firing (see Richardson et al. 1995; Stone 2003; Gordon et al. 2004; Smultea et al. 2004). However, during this project with small sources, observers were (at times) able to survey effectively out to distances beyond the estimated 160 dB re 1 µPa (rms) radius of 207–2469 m, depending on the seismic source used and the water depth (Table 4.8). Within those radii around the source, the distribution and behavior of cetaceans likely was altered as a result of the seismic survey, but beyond that distance such effects would be reduced, if present at all. Thus, in comparison with results from a project involving a larger airgun system, observations during seismic operations within the present project likely are more representative of the animals present in the absence of seismic operations.

To allow for animals missed during daylight, we corrected our visual observations for missed cetaceans by using approximate correction factors derived from previous studies. (It was not practical to derive study-specific correction factors during a survey of this type and duration.) It is recognized that the most appropriate correction factors will depend on specific observation procedures during different studies, ship speed, and other variables. Thus, use of correction factors derived from other studies is not ideal, but it provides more realistic estimates of numbers present than could be obtained without using data from other studies. To estimate numbers present and potentially affected during nighttime, we assumed that the corrected densities derived for daylight periods also applied to periods of darkness, as described in the *Analyses* section of Chapter 3.

The methodology used to estimate the areas exposed to received levels ≥160 dB, ≥170 dB, ≥180 dB and ≥190 dB and to estimate corrected marine mammal densities was described briefly in Chapter 3 *Analyses* and in further depth in Appendix D. Densities based on the number of sightings made during the cruise were calculated for both non-seismic and seismic periods for comparative purposes. The former represent the number of mammals expected to occur "naturally" within the area where disturbance is predicted (based on the 160 or 170 dB criteria). The latter represent the minimum number of mammals that apparently remained within the area exposed to strong GI gun pulses. Calculation of densities also accounted for shallow, intermediate and deep water depths. Separate calculations were done for the three depth strata because of ***(A)*** the different sound propagation properties and 160–190 dB radii in the different water depths (Table 4.8), and ***(B)*** potential water-depth effects on marine mammal densities (Fig. 4.2 and 4.3; Appendices H.1 to H.6).

The data resulting from the aforementioned corrected densities were used to estimate both the number of *individual* marine mammals exposed and the number of *exposures* of different individual marine mammals to these four isopleths, as appropriate to the species grouping. These numbers provide estimates of the number of cetaceans potentially disturbed by seismic operations. This dual approach was developed in a study of seals exposed to strong airgun sounds in the Alaskan Beaufort Sea (Harris et al. 2001; Moulton and Lawson 2002). The dual approach was later applied during various previous L-DEO projects, e.g., in the southeast Caribbean (Smultea et al. 2004) and northwest Atlantic (Haley and Koski 2004), among others. Because no pinnipeds were seen during the ETPCA survey, and their occurrence is considered unlikely in the region, the estimated numbers of pinnipeds exposed were zero.

A summary of the estimated numbers of cetaceans exposed to received GI gun sounds ≥160 dB (and ≥170 dB for delphinids) relative to the number of "takes" requested in the IHA application is found in Table 4.9. A similar summary of marine mammal exposures relative to GI gun sounds ≥180 dB is provided in Table 4.10. The data used to calculate these numbers, including densities by depth strata, for non-seismic as well as seismic periods, are presented in Appendices H.1–H.9 for the four criteria of interest. These results are summarized below.

Estimated Densities.—We made 68 sightings of 2004 marine mammals (all cetaceans) during 2734 km of "useable" survey effort (Table ES.1). The criteria for "useable" effort and sightings are given in *Acronyms and Abbreviations*. Of these, 26 sightings of 330 cetaceans occurred during useable non-seismic conditions, and 42 sightings of 1674 cetaceans occurred when 1 to 3 GI guns were operating. There was one additional sighting of three unidentified dolphins within the period 90 s to 2 h after the cessation of seismic surveys; these "post-seismic" sightings are not considered in this section (Appendix F.4).

TABLE 4.9. Maximum (exposures) and minimum (individuals) estimates of the number of marine mammals exposed to GI-gun sounds with received levels ≥160 dB (and ≥170 dB for delphinids) re 1 μPa (rms), based on observed densities during non-seismic and seismic periods during the ETPCA surveys. Also shown is the "harassment take" authorized by NMFS under the IHA.

	Estimated numbers exposed to ≥160 dB re 1 μPa (rms) (and ≥170 dB) based on observations during **seismic periods**				Estimated numbers exposed to ≥160 dB re 1 μPa (rms) (and ≥170 dB) based on observations during **non-seismic periods**				Requested take
	Exposures		Individuals		Exposures		Individuals		
Odontocetes									
Delphinidae									
Rough-toothed dolphin	0	(0)	0	(0)	0	(0)	0	(0)	269
Bottlenose dolphin	58	(18)	54	(17)	610	(191)	539	(183)	1782
Pantropical Spotted dolphin	173	(56)	152	(53)	369	(144)	326	(138)	5829
Spinner dolphin	863	(271)	757	(259)	0	(0)	0	(0)	6215
Striped dolphin	0	(0)	0	(0)	0	(0)	0	(0)	5819
Short-beaked common dolphin	0	(0)	0	(0)	52	(16)	50	(16)	2310
Unidentified common dolphin	0	(0)	0	(0)	53	(16)	50	(16)	2310
Fraser's dolphin	0	(0)	0	(0)	0	(0)	0	(0)	10
Risso's dolphin	0	(0)	0	(0)	29	(9)	28	(9)	391
Unidentified dolphin	232	(86)	206	(83)	619	(222)	550	(213)	
Melon-headed whale	0	(0)	0	(0)	0	(0)	0	(0)	189
Pygmy killer whale	0	(0)	0	(0)	0	(0)	0	(0)	176
False killer whale	35	(11)	33	(11)	0	(0)	0	(0)	5
Killer whale	0	(0)	0	(0)	0	(0)	0	(0)	5
Short-finned pilot whale	15	(5)	14	(4)	88	(27)	83	(27)	533
Total Delphinidae	**1376**	**(446)**	**1215**	**(427)**	**1819**	**(626)**	**1626**	**(601)**	**25843**
Physeteridae									
Sperm whale	0		0		0		0		82
Pygmy sperm whale	0		0		0		0		5
Dwarf sperm whale	0		0		0		0		503
Ziphiidae									
Cuvier's beaked whale	0		0		0		0		133
Tropical bottlenose whale	0		0		0		0		5
Pygmy beaked whale	0		0		0		0		14
Blainville's beaked whale	0		0		0		0		14
Mesoplodon sp. (unidentified)	0		0		0		0		
Unidentified toothed whale	0		0		7		7		
Mysticetes									
Humpback whale	69		61		0		0		2
Minke whale	0		0		0		0		2
Bryde's whale	0		0		0		0		*13*
Sei whale	0		0		0		0		2
Fin whale	0		0		0		0		2
Blue whale	0		0		0		0		11
Unidentified whale	5		4		*0*		0		
Total Non-Delphinids	**74**		**65**		**7**		**7**		**788**
Total Cetaceans	**1450**		**1280**		**1826**		**1632**		**26,631**
Pinnipeds									
South American fur seal	0	(0)	0	(0)	0	(0)	0	(0)	10
Southern sea lion	0	(0)	0	(0)	0	(0)	0	(0)	10
Galapagos fur seal	0	(0)	0	(0)	0	(0)	0	(0)	10
Galapagos sea lion	0	(0)	0	(0)	0	(0)	0	(0)	10
Total Pinnipeds	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	

Slight discrepancies in numbers within tables are due to rounding errors.

TABLE 4.10. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that would have been exposed to GI-gun sounds with received levels ≥180 dB (and ≥190 dB for less responsive species) in the Eastern Tropical Pacific Ocean off Central America, 21 Nov. to 22 Dec. 2004, if no animals had moved away from the active seismic vessel. Based on calculated densities[a] in seismic periods (e.g., Appendices H-4 to H-6). Sound sources were 1 to 3 GI guns each with a generator discharge volume of 45 or 105 in^3. Received levels of GI gun sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration). Species in italics are those listed under the U.S. ESA as endangered.

Species/species group	Exposures [b]		Individuals [b]	
Odontocetes				
Delphinidae				
Bottlenose dolphin	6	(2)	5	(2)
Pantropical spotted dolphin	18	(6)	17	(6)
Spinner dolphin	83	(26)	81	(26)
Unidentified dolphin	31	(15)	30	(15)
False killer whale	3	(1)	3	(1)
Short-finned pilot whale	1	(0)	1	(0)
Total Delphinidae	**141**	**(50)**	**139**	**(49)**
Physeteridae	0		0	
Ziphiidae	0		0	
Mysticetes				
Humpback whale	14		14	
Total Non-Delphinids	**14**		**14**	
Total Cetaceans	**155**		**153**	

[a] Values for *f* (0) and *g* (0) are from Koski et al. (1998) and Barlow (1999).

[b] Slight apparent discrepancies in totals result from rounding to integers.

Non-seismic Conditions: Appendices H.1, H.2 and H.3 summarize the average densities calculated from useable sightings and survey effort while the GI guns were silent and water depth was, respectively, shallow (<100 m), intermediate (100–1000 m), and deep (>1000 m). The survey effort and number of sightings were similar in intermediate-depth water and deep water. The overall estimated density of cetaceans was 173/1000 km^2 in intermediate-depth water—about half of the density in deep water (325/1000 km^2), and about twice the density recorded in shallow water (76/1000 km^2). The higher density in deep water was due to the larger mean group size there than in other depths. The shallow-water densities were based on few sightings and little survey effort, and may be less accurate than the estimates for the other depths. Bottlenose dolphins (87/1000 km^2) were the most abundant cetaceans in intermediate water depths and likely made up most of the unidentified dolphins (59/1000 km^2) there based on the small group sizes of unidentified dolphins. In deep water, short-finned pilot whales (67/1000 km^2) and several species of dolphins, including bottlenose, pantropical spotted, short-beaked common, and Risso's dolphin were moderately abundant (22–51/1000 km^2).

The overall densities of cetaceans during non-seismic periods within this 21 Nov.–22 Dec. 2004 study were lower than during the late July–early Dec. surveys reported by Ferguson and Barlow (2001). It is not known whether the difference is related to year-to-year or seasonal variation in density, or both. Also, the much lower survey effort during the ETPCA survey makes the estimated densities during this survey more uncertain. The sightings of humpback whales (16/1000 km^2 in shallow water and 0.5/1000 km^2 in intermediate water depth) during this survey are of special interest, as described previously. Humpback whales were not sighted during the earlier surveys reported by Ferguson and Barlow (2001) and were not expected to be encountered in significant numbers during this cruise.

GI Guns Operating: Appendices H.4, H.5 and H.6 summarize the results while one or more GI guns were firing in the three water depth categories. In all water depths there was more survey effort during seismic periods than during non-seismic periods. In shallow water, the densities of cetaceans during seismic periods (36/1000 km^2) were about half of those during non-seismic periods (76/1000 km^2); however, the effort during non-seismic periods was too low to provide a reliable density estimate. In deep water, the densities during seismic (90/1000 km^2) were about one quarter of those during non-seismic periods (325/1000 km^2). In intermediate water depths, where the greatest survey effort occurred, the density during seismic periods (188/1000 km^2) was slightly (1.1×) higher than during non-seismic periods (173/1000 km^2). The higher density during seismic periods in intermediate water depths was due to three sightings of large groups of spinner dolphins (138/1000 km^2) that made up 73% of the cetaceans estimated to have been present.

In summary, the "useable" survey effort in all water depths was very limited during non-seismic periods and also very limited in shallow and deep water during seismic periods. The overall densities of cetaceans recorded during this survey were lower than during earlier surveys. However, the effort was too low to properly evaluate the effects of the present low-energy seismic survey on marine mammal distribution and density near the seismic vessel. Many species that were seen during the earlier surveys reported by Ferguson and Barlow (2001) were not seen during this survey, presumably because of the low survey effort. However, one species (humpback whale) that was not recorded during the earlier surveys was relatively common during the ETPCA survey.

***Estimated Numbers of Cetaceans Exposed to ≥160 or ≥170 dB*.—**It is assumed that cetaceans (aside from delphinids) are likely to be disturbed appreciably if exposed to received levels of seismic pulses ≥160 dB re 1 μPa (rms). It is assumed that delphinids are unlikely to be disturbed appreciably unless exposed to received levels ≥170 dB. These are not considered to be "all-or-nothing" criteria; some individual mammals may react strongly at lower received levels, but others are unlikely to react strongly unless levels are substantially above 160 or 170 dB.

Estimates Based on Densities during Non-seismic Periods: "Corrected" densities of cetaceans observed during non-seismic periods in water depths >100, 100–1000, and >1000 m are presented in Appendices H.1 to H.3. The corrected densities were used to estimate the number of cetaceans that were potentially disturbed by seismic operations (Table 4.9).

(A) 160 dB (rms): The overall estimates of the numbers of individuals exposed to ≥160 dB total 7 individuals and 7 exposures for cetaceans other than delphinids, and 1626 individuals and 1819 exposures for delphinids (Table 4.9). These "individuals" estimates would be reasonable if the cetaceans remained stationary throughout the study, but that is unlikely. Thus, the actual numbers of individuals exposed to ≥160 dB re 1 μPa (rms) are expected to be somewhere between the "exposures" and "individuals" estimates shown in Table 4.9.

(B) 170 dB (rms): On average, delphinids may be disturbed only if exposed to received levels of GI gun sounds ≥170 dB re 1 μPa (rms). If so, then the estimated number of exposures of these cetaceans would be one third to one half of the delphinid estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB than ≥160 dB (see Appendix D.2). This is a result of the smaller 170 dB radii

as compared with 160 dB radii. The specific estimates depend on the water depth and whether or not the area ensonified includes or excludes overlap. Overall, based on densities estimated from surveys during non-seismic periods, the estimated number of delphinid exposures to ≥170 dB was 626, which is ~34% of the expected exposures of those taxa to ≥160 dB (1819).[2]

Estimates Based on Densities during Seismic Periods: During seismic periods, overall densities near the survey vessel were estimated to be lower in shallow and deep water and slightly higher in intermediate water depths than those in corresponding water depths during non-seismic periods (Appendices H.4 to H.6). The estimated numbers of exposures and the minimum numbers of individual cetaceans that may have been exposed to seismic sounds with received levels ≥160 dB, and for delphinids ≥170 dB, are summarized in Table 4.9. For additional details, see Appendix H.8.

Cetaceans Potentially Exposed to Sounds ≥180 dB.—Most cetaceans that were at the surface within the relatively small 180 dB radii (Table 4.8) during daylight observation periods would have been seen by the observers. Based on the densities of cetaceans estimated from observations during seismic periods, ~155 cetacean exposures and 153 individuals would have been expected to have occurred within the 180 dB radius of the operating GI guns *if the animals did not move away from the approaching seismic vessel* (Table 4.10). These estimates are ~51 times higher than the 3 different individual cetaceans that direct observations indicated were likely exposed to ≥180 dB (Table 4.7). However, the former estimates (153–155 apply to day and night, whereas the latter estimate applied mainly to daylight seismic operations. Also, the ~153–155 estimates include any animals that moved away as the seismic vessel approached, possibly before being in visual range for the MMOs. Furthermore, the 153–155 estimates include correction factors for animals missed because they were below the surface or for other reasons.

The overall estimate (153–155) of the number of cetaceans either exposed to ≥180 dB, or avoiding such exposure by moving away, should be fairly reliable: it is based on moderate numbers of sightings in the water depth category where the majority of the seismic activity occurred. However, the estimates for individual species are quite uncertain. Most estimates are based on zero to few sightings, and are subject to considerable random sampling error.

Summary of Exposure Estimates.—Estimates of the numbers of exposures to strong sounds are considered *maximum* estimates of the number of mammals exposed. In this method, repeated exposures of some of the same animals are counted separately, with no allowance for overlapping survey lines. This method also assumes that no mammals show avoidance of the approaching seismic vessel before received sound levels reach the sound level in question. Based on densities of cetaceans observed during non-seismic periods, a maximum of ~1826 potential cetacean exposures to GI gun sounds with received levels ≥160 dB re 1 μPa were estimated to have occurred during the seismic survey. The estimates are lower if based on number of individuals exposed to ≥160 dB, or if the alternative ≥170 dB criterion is applied for delphinids (Table 4.9).

The highest overall estimate of exposures to ≥160 dB (n = 1826) is only about 7% of the potential "take" estimated in the IHA Application. There are two reasons for the difference. First, the requested take authorization was based on ***maximum*** numbers of marine mammals that might occur in the survey area during the survey period, an approach that tends to overestimate the number ***likely*** to be there. Second, the size of the

[2] Different densities of cetaceans were recorded in different water depths (Appendices H.1 to H.3). As a result, the difference in the ≥170 dB vs. ≥160 dB estimates is not directly proportional to the difference in the total areas estimated to be exposed to those sound levels (see Appendix D.2).

seismic source was reduced in most situations from the source assumed in the IHA application. By reducing the source level, the area that was ensonified to ≥160 dB was reduced and fewer animals were exposed to seismic sounds that might alter their behavior. Note that the 1826 estimate *does* include approximate allowance for animals missed by the observers during both daytime and night. That allowance is based on application of "best available" correction factors for missed animals (i.e., $f(0)$ and $g(0)$ factors), and an assumption that encounter rates at night were the same as those by day.

Summary and Conclusions

Results of L-DEO's ETPCA marine mammal monitoring program provide concentrated survey effort near the little-studied Pacific coasts of Honduras, Nicaragua, and northern Costa Rica during Nov. and Dec. Over 4965 km of visual observation effort, and 5200 km of passive acoustic monitoring effort were conducted during the cruise; ~55% of visual effort was during "useable" conditions, as defined in *Acronyms and Abbreviations*. Behavior and density analyses were limited to "useable" sightings, and consisted of an estimated 2004 cetaceans in 68 groups. No injured marine mammals potentially associated with the operations were sighted.

A total of nine different cetacean species were identified during the study, and one or more additional species were seen that were not identified to species level. Based on useable sightings, the humpback whale (n = 11 groups) and bottlenose and pantropical spotted dolphins (n = 8 groups each) were the most commonly seen species. The spinner dolphin (n = 3 groups; ~1350 individuals) was the most numerous cetacean. No pinnipeds were sighted. For the first time during a *Ewing* seismic cruise, two cetacean groups were initially sighted at night with the NVDs. This is the first indication that the NVDs used by MMOs to conduct nighttime visual observations are indeed useful to visually detect some delphinids near the *Ewing* under at least some viewing conditions.

Humpback whales were not expected to occur in the survey area; however, they were described in the IHA Application as a species that might be encountered. A total of 16 humpbacks in 11 groups were sighted during the cruise. Most (n = 12) of these whales were seen on 9 Dec. in the shallow waters of the Gulf of Fonseca near the west coast of Honduras. Two of these individuals were also recorded singing. Little is known about humpbacks in this coastal area. Also, a humpback mother-calf pair was seen northeast of the Nicoya Peninsula off northern Costa Rica. Studies off Costa Rica indicate that both northern and southern populations use this area during their respective winters. The timing (25 Nov.) of the mother-calf sighting during the ETPCA cruise suggests that this pair may have been from the southern hemisphere population of humpbacks.

Results suggest that the low-intensity seismic sound sources used during this cruise may have displaced or affected the behavior of some cetaceans near the *Ewing,* but if this did occur, the zone of influence was small. However, interpretation is limited by the small sample sizes. The sighting rates of cetaceans during "useable" non-seismic periods were higher than during seismic periods. Delphinids and whales tended to be sighted farther from the observation vessel during seismic than during non-seismic periods, although the sample sizes were small with large standard deviations. Bowriding delphinids were seen on nine occasions: eight during seismic periods and once during a non-seismic period. While bowriding at or near the surface, cetaceans would receive lower sound pressure levels relative to those at depth because of the pressure-release effect at the surface.

A single pantropical dolphin followed, circled, and sometimes vocalized near the *Ewing* over a period of ~26 h during both seismic and non-seismic periods. The observations suggest that this individual may have become habituated to the GI gun sounds. Observations suggest that this individual was not displaced by the GI gun sounds, but may have been attracted by the ship or the GI gun pulses.

During the ETPCA survey, acoustic detection rates were higher than visual detection rates, which is typical for joint visual/acoustic surveys. Because PAM effort in the absence of seismic operations was so limited during this cruise, it was not possible to determine whether acoustic detection rates were significantly different during seismic vs. non-seismic periods. The ETPCA acoustic monitoring results (and some previous studies) indicate that at least some cetaceans call in the presence of airgun and GI gun pulses. The lone pantropical dolphin that was seen and heard vocalizing near the *Ewing* for ~26 h during both seismic and non-seismic periods was one example.

During this project, four shut downs were initiated when three different cetacean groups were seen in or near the designated safety radius for the GI guns and water depth in effect at the time. These incidents involved two different groups of humpbacks totaling three individuals, and the same lone pantropical spotted dolphin on two different days. All three of these cetacean groups were likely exposed to GI gun sounds with received levels ≥180 dB re 1 µPa (rms). An additional eight power downs were implemented: two for humpbacks and six for delphinids. However, it is unlikely that any of these ~39 different individuals were exposed to GI gun sound levels ≥180 dB.

Based on *direct* observations, the estimated number of individual cetaceans exposed to various levels of seismic sound pulses were as follows:

- Three cetaceans (including two humpbacks and one dolphin) were seen where received levels were estimated to be ***≥180 dB*** re 1 µPa (rms);
- 11 delphinid groups involving 88 different individuals were seen where received levels were estimated to be ***≥170 dB***; and
- 32 cetacean groups (238 different delphinids + 10 non-delphinids) were seen where received levels were estimated to be ***≥160 dB***. (However, a more realistic estimate of the number of delphinids potentially disturbed by seismic sounds is the number exposed to ≥170 dB.)

In summary, a total of 98 individual cetaceans were *directly* observed to have been exposed to GI gun sounds at estimated levels that could have potentially disturbed them. This includes 10 individual non-delphinids exposed to seismic sounds ≥160 dB re 1 µPa (rms), and 88 individual delphinids exposed to sounds ≥170 dB. Additional cetaceans, most likely delphinids, were probably present within the ≥160 or ≥170 dB zones during nighttime seismic operations.

Densities of marine mammals within the seismic study area were calculated based on "useable" survey data from seismic and non-seismic periods, stratifying by water depths <100, 100–1000 m and >1000 m. Effort was highest in intermediate water and lower in shallow and deep water, and densities during seismic were lower than densities during non-seismic periods; however, because of low effort, these densities are not reliable.

Minimum and maximum estimates of numbers of cetaceans in areas exposed to GI gun sounds are shown in Table 4.9 based on the densities estimated from surveys during seismic and non-seismic periods. Also shown, for comparison, are the numbers of "harassment takes" that were requested by L-DEO in the IHA application. Except for humpback whales and false killer whales, all estimates based on actual density data are lower than the "harassment takes" estimated prior to the survey. The total estimated maximum number of cetaceans in areas exposed to ≥160 dB is about ~7% of the maximum number estimated in the IHA application.

For cetaceans, the overall estimates of numbers exposed to seismic sounds ≥160 dB were ~34% higher when based on densities estimated for non-seismic vs. seismic periods. This difference suggests that some cetaceans may have avoided the seismic vessel at very close range, or that some animals may have changed their behavior in ways that made them less conspicuous to observers. However, the potential radius of effect appeared to be quite small. This is not surprising, given the small sound source used in this project as compared with most seismic surveys.

5. SEA TURTLES

Introduction

This chapter describes the results of the sea turtle monitoring program. The chapter begins with a review of the status of sea turtles occurring in the study area in the ETPCA, and then presents the results of the sea turtle monitoring program. The chapter ends with a brief summary and conclusions section. An overview of program operations was provided in Chapter 2, and the mitigation and monitoring programs were described in Chapter 3. A list of all sea turtle sightings during the ETPCA cruise is located in Appendix I.1.

Status of Sea Turtles in the Area

Several species of sea turtles are known to occur in the ETPCA: the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), and olive ridley (*Lepidochelys olivacea*) turtles. Some of those species are known to nest on the Pacific coast of Central America.

The loggerhead, olive ridley, and green turtles are currently listed as Threatened Species under the U.S. Endangered Species Act, and the leatherback and hawksbill turtles are listed as Endangered Species. The IUCN–World Conservation Union Red List (IUCN 2003) classifies leatherback and hawksbill turtles as Critically Endangered, and loggerhead, olive ridley, and green turtles as Endangered. Mexico, Honduras, Costa Rica, Nicaragua, and the United States are all signatories of the Inter-American Convention for the Protection and Conservation of Sea Turtles, and all but Nicaragua have ratified the Convention (Seaturtle.org 2003). El Salvador is not a signatory.

Sea turtles share a common life cycle with slight variations among species (see Miller 1997). All species migrate between foraging areas and nesting areas. Migration routes may exceed 2600 km, but most sea turtles travel less than 1000 km (Miller 1997). Females of most species nest every two to four years, although females of some species nest annually. After mating, males generally return to feeding areas, whereas females come ashore at traditional nesting beaches to lay eggs. Within a few months, females lay up to 10 clutches of about 100 eggs in nests buried on beaches. The eggs incubate for about two months, and then the hatchlings move into the sea where they begin their extended pelagic phase of development. Later, juveniles of most species enter the coastal zone or move into bays and estuaries, where they mature 10 to 50 years later.

Sea turtles spend most of their time at sea, and generally only return to land to nest. Most species are widely distributed, but their habitat preferences vary. All except the leatherback turtle, olive ridley, and some populations of green turtles are believed to be primarily coastal when not breeding (EuroTurtle 2001). The leatherback sea turtle is highly oceanic, and only occurs in coastal areas during the breeding season.

Nesting Areas

The survey occurred in water depths up to 5000 m, and extended from ~150 km offshore almost to the shoreline. Several sea turtle nesting beaches are known near the survey area, including La Flor National Wildlife Refuge and Chacocente National Wildlife Refuge in Nicaragua, the Nicoya Peninsula in Costa Rica, and various locations in El Salvador and Honduras (Fig. 5.1). Because of the proximity of the study area to many sea turtle nesting sites, special precautionary monitoring and mitigation measures were implemented during this project (Chapter 3 and below).

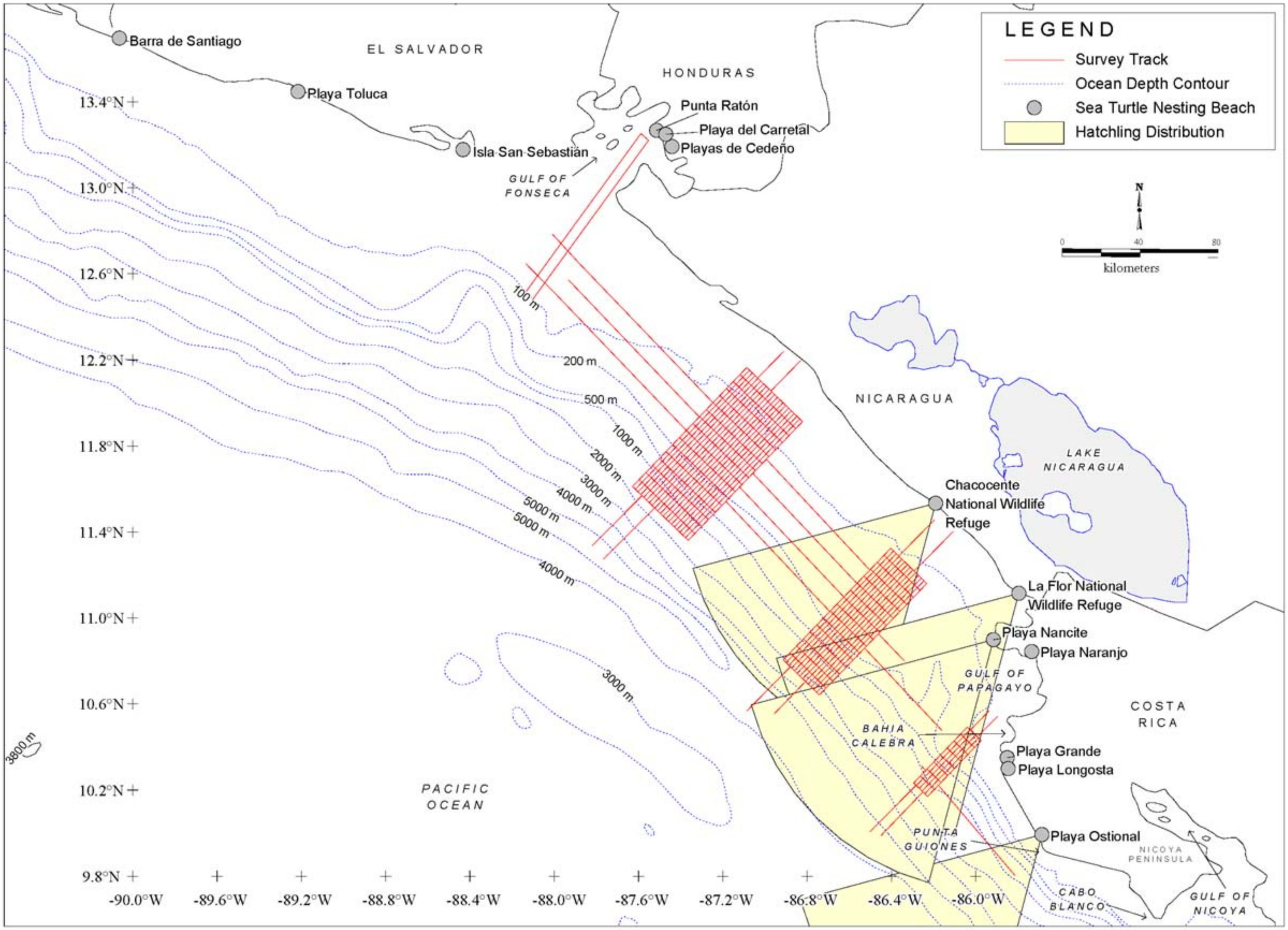

FIGURE 5.1. Anticipated distribution of olive ridley sea turtle hatchlings from the Oct. 2004 nesting arribadas at the four major nesting beaches on the west coasts of Costa Rica and Nicaragua, and the general location of seismic track lines during the ETPCA seismic cruise 21 Nov.–22 Dec. 2004.

Loggerhead turtles.—Most of the loggerheads that nest in the eastern Pacific are believed to originate from beaches in Japan. There are no reported loggerhead nesting sites in the eastern or central Pacific (NMFS 2002). Nesting of loggerheads in El Salvador has been reported but not confirmed; most researchers believe that the turtles were misidentified olive ridley turtles (Hasbún and Vásquez 1999).

Green turtles.—In the eastern Pacific, the primary nesting grounds for green sea turtles are located in Michoacán, Mexico, and the Galapagos Islands, Ecuador (NMFS and USFWS 1998). Nesting occurs in Michoacán from Aug. to Jan., with a peak in Oct.–Nov., and on the Galapagos Islands from Dec. to May with a peak in Feb. (Alvarado and Figueroa 1995). In Central America, small numbers of green turtles nest at major nesting sites of other species, primarily olive ridleys, in Nicaragua at Chacocente and La Flor National Wildlife Refuges, and in Costa Rica at Playa Ostional (Marine Turtle Research Center 2003; Fig. 5.1). Green (black) turtles also nest in very small numbers in El Salvador (Hasbún and Vásquez 1999).

Hawksbill turtles.—No major nesting sites for hawksbill turtles occur on the Pacific coast of Central America (EuroTurtle 2001), although a few hawksbills are known to nest at the La Flor National Wildlife Refuge in Nicaragua and at Playa Nancite in Santa Rosa National Park in Costa Rica (Marine Turtle Research Center 2003; Fig. 5.1). Hawksbill turtles also reportedly nested at Barra de Santiago in El Salvador three decades ago, but today only occur there sporadically (Hasbún and Vásquez 1999). The nesting season of the hawksbill turtle is ~6 mo in duration. Nesting generally occurs from June to Dec, preceded by courtship and mating.

Olive ridley turtles.—In El Salvador, the olive ridley nests year round, but nesting activity is concentrated during the rainy season from May to Oct., peaking in Aug. and Sept. (Hasbún & Vasquez 1991 *in* Hasbún & Vasquez 1999). Nesting beaches occur at Barra de Santiago and Playa Hermosa on Isla San Sebastián (Hasbún and Vasquez 1999). At Playa Toluca, 102 nests were seen in July and Aug. 2001 (Menjivar 2002). Nesting beach locations are shown in Figure 5.1. A small number of olive ridley turtles are caught in El Salvador's Pacific shrimp fishery (e.g., ~30 during Sept.–Oct. 1992; Arauz 1996).

In Honduras, olive ridleys nest on many islands in the Gulf of Fonseca and on the mainland from the border with Nicaragua to Punta Novillo, located on the west side of Isla Zacate Grande. Over half of the nesting occurs at three mainland sites (see Fig. 5.1): Punta Raton, Cedeño, and El Carretal (C. Lagueux, Univ. Florida, *in* NMFS and USFWS 1998). Cornelius (1982) cited an estimate of 3000 nesting females for all of Pacific Honduras and reported that the population was declining. In 1987, olive ridleys laid an estimated 2000 clutches in Pacific Honduras, i.e., ~1000 nesting females (C. Lagueux, *in* NMFS and USFWS 1998).

In Nicaragua, two major olive ridley nesting sites exist: Chacocente and La Flor National Wildlife Refuges (see Fig. 5.1), where some 40,000 and 30,000 olive ridley turtles nest, respectively, beginning in July and ending in Jan. During Aug. 1993–Jan. 1994 at Playa La Flor, six arribadas (periods of mass synchronous nesting) occurred, arriving every 23–30 days (Ruiz 1994). They were 2–4 days in length, with turtle numbers ranging from 1393 to 8886 per arribada. The highest numbers were in early Oct. (8886), early Nov. (6400), and late Nov. (5189). In late Dec., 1650 turtles nested, and none came in Jan. In 1994, the largest arribadas took place in Aug. and Sept. (Cerna et al. 1996).

In Costa Rica, there are ~60 sea turtle nesting beaches, with two of the most important Pacific beaches located on the Nicoya Peninsula (Fig. 5.1): Playa Nancite at Santa Rosa National Park, and Playa Ostional (Marine Turtle Research Center 2003). Playa Ostional and Playa Nancite (see Fig. 5.1) are considered the two most important nesting beaches for olive ridleys in the world: 450,000–600,000 nest at Playa Ostional, and 25,000–50,000 nest at Playa Nancite each year (NMFS and USFWS 1998). Nesting occurs from May to Dec. at Nancite and year round at Ostional, although the biggest arribadas (~120,000 turtles) occur during the May–Oct. rainy season (Chaves et al. 1994).

***Leatherback turtles*.**—In the Pacific, leatherbacks nest along the west coast of Mexico and Central America from Sept. to March. Nesting is also known to occur sporadically in El Salvador during the dry months from Nov. to Feb. (Hasbún and Vásquez 1999). Leatherbacks also nest in Panama and Colombia. Females may lay up to nine clutches in a season (although six is more common), and the incubation period is 58–65 days. At Playa Grande, Costa Rica, and in French Guiana, the mean inter-nesting period was 9 days (Lux et al. 2003). During an aerial survey in Jan.–Feb. 1999, Sarti et al. (2000) recorded 4, 0, 61, and 11 nestings in El Salvador, Honduras, Nicaragua, and Costa Rica, respectively. (The most important nesting beaches in Costa Rica, Playa Grande and Playa Langosta, were not surveyed.) Recent estimates of the number of nesting females in the eastern Pacific population are 1600–1700 (NMFS 2002).

In Costa Rica, leatherbacks nest at Playa Naranjo in Santa Rosa National Park and at various beaches in Las Baulas National Park including Playa Langosta and Playa Grande (Marine Turtle Research Center 2003). At Playa Naranjo, track counts were 312–1212 during several months of the nesting season in 1983–84, 1989–90, and 1990–91 (Araúz-Almengor and Morera-Avila 1994). Playa Grande (see Fig. 5.1) is the fourth-largest leatherback nesting colony in the world (NMFS 2002). The number of leatherback turtles nesting in Las Baulas National Park has been declining steadily. During the 1988–89 nesting season, ~1500 females nested; that had declined to ~800 in 1990–91 and 1991–92, and to 193 in 1993–94 (Williams et al. 1996). Only 117 turtles nested in 1998–99 (Spotila 2000 *in* NMFS 2002).

At Playa Grande during Oct. 2000–Feb. 2001, leatherback nesting showed a weak but predictable positive response to nightly high-tide time, but no circa-lunar behavior was detected (Lux et al. 2003). Nesting activity increased gradually from Oct. to Dec., and then gradually declined until Feb.

Monitoring and Mitigation

Monitoring and mitigation requirements for sea turtles, as identified in the IHA (Appendix A), are summarized in Chapter 3 along with those for marine mammals. Extra mitigation and monitoring requirements for sea turtles were given in the Incidental Take Statement (ITS; see Appendix A). Monitoring and mitigation measures specifically implemented for sea turtles are described below (and Chapter 3). In this project, the IHA required that ramp up of the GI guns be delayed if a sea turtle was seen within the safety radius. Also, it required that the GI guns be powered down or shut down if a turtle was seen within or about to enter the safety radius while the guns were operating.

Observers diligently monitored for sea turtles near the *Ewing* during all daytime GI gun operations and during nighttime ramp ups, as required by the IHA. In addition, nighttime watches were conducted while seismic operations occurred near sea turtle nesting areas, as specified in the ITS. As a precautionary measure, NMFS required that the 170 dB re 1 μPa (rms) sound radius be used as the edge of the "safety zone" for turtles during this study, rather than the 180 or 190 dB radius used during previous L-DEO seismic studies. In addition, although two configurations of three GI guns with different total volumes (315 in^3 and 135 in^3) were employed during the survey, the 170 dB sound radius applicable to the larger configuration was used when either the larger or smaller configuration was operating.

Visual Monitoring Results

Sea Turtle Sightings

A total of 171 sea turtle sightings involving 179 individual turtles occurred from the *Ewing* during the ETPCA cruise (Fig. 5.2, Appendix I.1). Three species of sea turtles were identified, including 84 individual olive ridleys, 1 leatherback, and 2 possible green sea turtles. The remaining 92 individual sea turtles were recorded as unidentified turtles. Of the total 171 turtle groups seen, 117 or 68% were sighted during "useable" survey conditions (defined in *Acronyms and Abbreviations*; see Table 5.1). This excludes a total of 43 additional turtle groups (46 individuals) sighted during the "post seismic" periods (90 s to 2 h after seismic operations had ceased). Also excluded are 5 "groups" of 5 individual dead sea turtles, 5 sightings of individual turtles in glare, and 1 sighting of a single turtle during darkness (see below). The 43 non-useable groups sighted during post-seismic periods included 15 groups (15 indiv.) of olive ridley sea turtles and 28 groups (31 indiv.) of unidentified sea turtles. The 5 non-useable sightings that occurred during periods of glare consisted of 4 single olive ridley turtles and 1 unidentified sea turtle. The single turtle observed in the dark was unidentified. Analyses described below were limited to the 117 "useable" sightings (i.e., groups), similar to cetacean analyses described in Chapter 4.

The five dead sea turtles included one possible green sea turtle and four unidentified sea turtles (Appendix I.1). None of these dead turtles qualify as "useable" data. All five dead turtles were adults, with shell lengths of ~1 m. Two of the sightings, including the possible green turtle, were of turtle carcasses with bleached shells, indicating that the turtles had been floating for a significant period of time. Another sighting was of a turtle that appeared to have been subject to predation: it was floating ventral-side up with its entrails visible. The other two sightings were of turtle shells only. For each of these sightings, the observers concluded that the turtle had been dead for an extended period and had not been injured or killed by the seismic operations then in progress. Thus, seismic activities were not suspended for any of the dead turtle sightings. NMFS was notified of several of these dead turtles on 27 Nov. 2004.

Most (66%) of the total 171 turtle sightings were made while seismic operations were underway (113 sightings) vs. 58 sightings during other periods (Table 5.1). Ramp ups were interrupted four times because of the presence of sea turtles, and ramp ups had to be postponed on numerous occasions due to sea turtles within the 170 dB radius (Appendices I.1 and I.2). The ITS required power downs or shut downs when sea turtles were seen within the 170 dB radius while the GI guns were in operation. The GI guns were powered down 16 times and shut down 71 times because of the presence of sea turtles within the 170 dB sound radius during the ETPCA cruise (Appendices I.1 and I.2). None of the shut downs was due to a turtle moving into the 170 dB sound radii after a power down.

During the night of 28 Nov., a marine mammal observer sighted an unidentified sea turtle within 107 m of the 3-GI-gun array and implemented a shut down (Appendices I.1 and I.2). With the assistance of NVDs, the observer was able to clearly discern a carapace and the turtle's logging motions. This was the first incident during an L-DEO seismic survey of a sea turtle sighting in darkness. The sighting was, to a great extent, attributed to the calm sea state (Beaufort Force 1; Appendix I.1).

Distribution

The highest number of sea turtle sightings occurred in the Northern Sandino Basin (NSB) area and the lowest number occurred in the Southern Sandino Basin (SSB) (Fig. 5.2). Because of the proximity of the SSB area to turtle nesting sites at Chacocente and La Flor National Wildlife Refuge, as well as several other beaches to the south (Fig 5.1), high densities were expected there. However, the high numbers

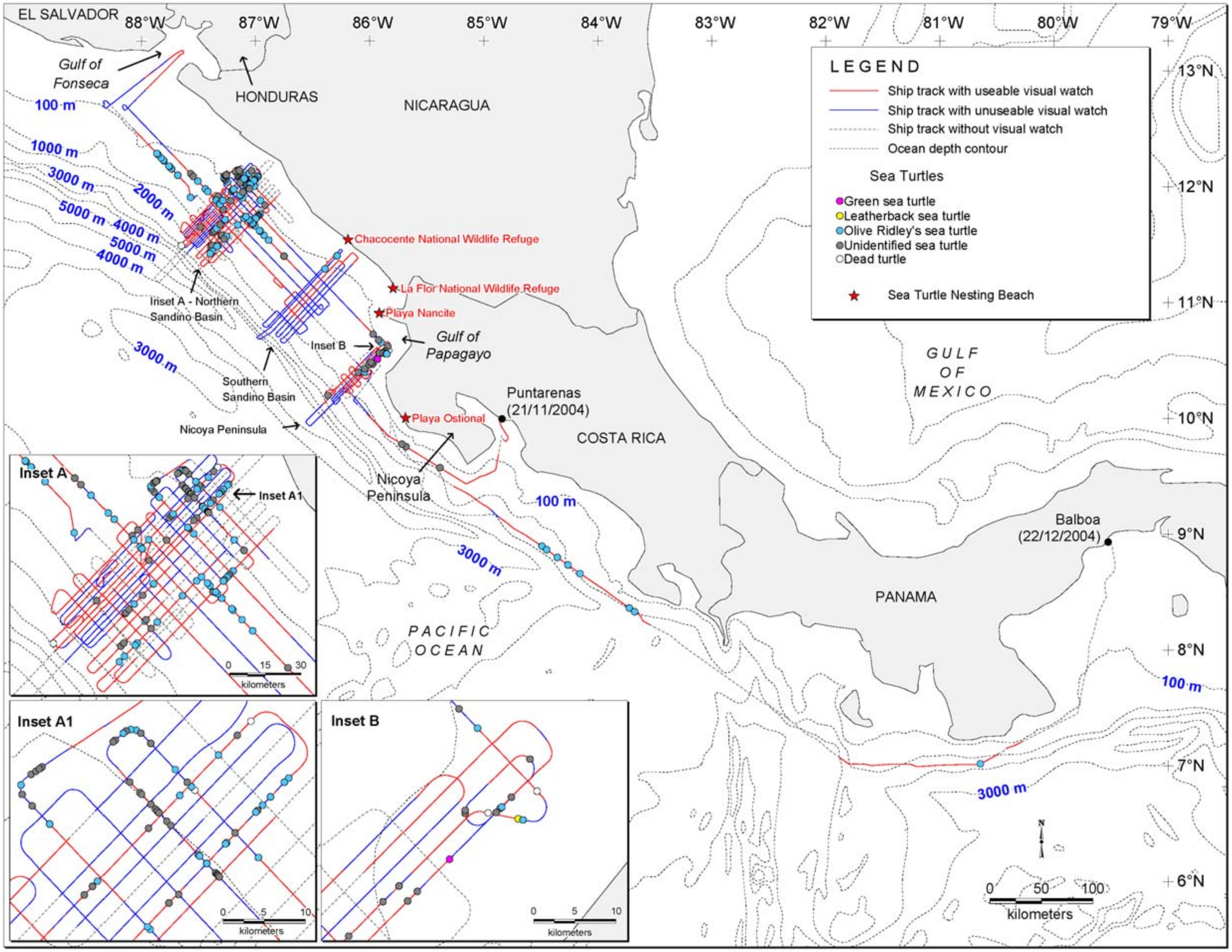

FIGURE 5.2. Locations of all sea turtles showing periods with useable vs. useable survey effort during the ETPCA seismic cruise, Nov.–Dec. 2004.

TABLE 5.1. Number of useable[a] sea turtle sightings, group and individual, during seismic and non-seismic periods during the 21 Nov.–22 Dec. 2004 ETPCA seismic cruise.

	Seismic		Non-seismic		Total Useable	
Sea turtle species	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.
Green sea turtle	-	-	1	1	1	1
Leatherback sea turtle	1	1	-	-	1	1
Olive ridley sea turtle	54	56	9	9	63	65
Unidentified sea turtle	47	50	5	5	52	55
Total	102	107	15	15	117	122

[a] Useable sightings are those made during useable daylight periods of visual observation, as defined in *Acronyms and Abbreviations* This excludes 43 turtle groups seen during the "post-seismic" period, 5 dead sea turtles, 5 sightings in glare, and one sighting at night.

witnessed in the NSB were unexpected, because there are no known nesting beaches near that area. It is possible that sea turtles use the NSB area as a migration route to the nesting beaches in the south. Also, it is possible that the low densities observed in the SSB can be attributed to the predominantly poor sight ability conditions during survey effort in that area. The number of cetaceans sighted in the SSB was also low (Chapter 4), but acoustic detections of cetaceans were frequent in the SSB; this further suggests that the low sighting rates were attributable to poor sighting conditions (see Fig. 4.2).

Overall, the majority (84 or 72%) of the 117 "useable" sea turtle groups were seen in water 100–1000 m deep, where most of the observer effort occurred (Appendices F.1 and I.3). Most of those sightings were during seismic periods. The majority of the sightings during non-seismic periods (8, or 53%) were in water >1000 m deep, but the sample size during non-seismic periods was small (n = 15).

Behavior

Behavioral data were collected for all sea turtle sightings in terms of estimated closest observed point of approach to the array, movement, and behavior (Tables 5.2–5.4). The data described here are limited to "useable" turtle sightings.

Closest Observed Point of Approach. —On average, turtles were observed closer to the GI gun array when the guns were off (mean 127 m, n =15) than while the GI guns were on (320 m, n =102; Table 5.2). However, standard deviations were large for both the seismic and non-seismic sightings (Table 5.2). It is interesting to note that, when the "seismic" data were subdivided according to array volume, the five groups of turtles observed when the array volume was >135 in^3 tended to be closer than those seen when array volume was ≤135 in^3 (mean CPA = 163 vs. 328 m).

Movement.—Of 117 "useable" turtle groups where the first movement was noted, nearly all (n = 108 or 92%) were seen while the GI guns were operating (Table 5.3). During seismic operations, the most frequently observed type of movement was "none". Of those recorded as moving in a specific direction, the proportions moving "away" vs. "toward" were not markedly different during seismic operations (Table 5.3). During non-seismic periods, 87% of the turtle groups were first recorded as not moving (12 of 15).

TABLE 5.2. Closest observed points of approach (CPA) of turtles to the GI guns relative to GI gun volume during the ETPCA cruise, 21 Nov.–22 Dec. 2004. Data are limited to "useable" turtle sightings.

			Seismic				Non-seismic			
Species or Group	**No. of Groups**	**Array Volume**	**Mean CPA (m)**	**SD**	***n***	**Range (m)**	**Mean CPA (m)**	**SD**	***n***	**Range (m)**
Turtles	112	≤ 135	328	487	97	5-3151	127	212	15	1-689
	5	>135	163	71	5	87-254	-	-	-	-
Total	117		320	477	102	5-3151	127	212	15	1-689

[a] Useable sightings are those made during useable daylight periods of visual observation, as defined in *Acronyms and Abbreviations* This excludes 43 turtle groups seen during the "post-seismic" period, 5 dead sea turtles, 5 sightings in glare and one sighting at night.

TABLE 5.3. Comparison of sea turtle groups' direction of movement during non-seismic and seismic periods during the ETPCA cruise, 21 Nov.–22 Dec. 2005. Only "useable"[a] data are included. See Appendix D for a description of movement categories.

	Direction of Movement-Seismic						Direction of Movement-Non-seismic						
Species	**None**	**Away**	**Parallel**	**Toward**	**Unknown**	**Sub-Total**	**None**	**Away**	**Parallel**	**Toward**	**Unknown**	**Sub-Total**	**GRAND TOTAL**
Green sea turtle	-	-	-	-	-		**1**	-	-	-	-	**1**	**1**
Leatherback	-	-	-	**1**	-	**1**	-	-	-	-	-	-	**1**
Olive ridley sea turtle	**44**	**4**	**7**	**2**	**1**	**58**	**7**	-	**1**	**1**	-	**9**	**63**
Unidentified turtles	**38**	**4**	**5**	**2**	-	**49**	**5**	-	-	-	-	**5**	**52**
Total	**77**	**8**	**12**	**5**	**1**	**108**	**13**	**0**	**1**	**1**	**0**	**15**	**117**

[a] Useable detections are those made during useable daylight visual observations as defined in Acronyms and Abbreviations and in Chapter 3 Analyses. This excludes a total of 43 turtle sightings that occurred during the "post-seismic" period and 5 sightings of dead sea turtles, 5 sightings of turtles in glare, and 1 sea turtle sighting in darkness.

TABLE 5.4. First observed behavior by sea turtle groups during non-seismic and seismic periods during the ETPCA cruise, 21 Nov.-22 Dec 2005. Only "useable"[a] data are included. See Appendix D for a description of movement categories.

	First Observed Behavior - Seismic						First Observed Behavior - Non-seismic						
Species	**Dive**	**Log**	**Rest**	**Swim**	**Mate**	**Sub-Total**	**Dive**	**Log**	**Rest**	**Swim**	**Mate**	**Sub-Total**	**GRAND TOTAL**
Green sea turtle	-	-	-	-	-	-	-	**1**	-	-	-	**1**	**1**
Leatherback		-	-	**1**	-	**1**	-	-	-	-	-	-	**1**
Olive ridley sea turtle	**3**	**38**	-	**12**	**1**	**58**	-	**6**	**1**	**2**	-	**9**	**63**
Unidentified turtles	-	**35**	-	**10**	**2**	**49**	-	**5**	-	-	-	**5**	**52**
Total	**3**	**73**	**0**	**23**	**3**	**108**	**0**	**12**	**1**	**2**	**0**	**15**	**117**

[a] Useable detections are those made during useable daylight visual observations as defined in *Acronyms and Abbreviations* and in Chapter 3 *Analyses*. This excludes a total of 43 turtle sightings that occurred during the "post-seismic" period and 5 sightings of dead sea turtles.

***Behavior*.—**Overall, most (n = 85 or 73%) of the 117 "useable" sea turtle groups were first observed logging, i.e., not actively moving relative to the ship; 85% of these 85 groups were sighted during seismic operations (Table 5.4). Logging accounted for 72% of the 102 sightings during seismic operations and 80% of the 15 seen during non-seismic conditions. Swimming was the second most frequently observed behavior during seismic periods (23 of 108 groups or 21%). Swimming was also recorded during non-seismic periods (2 of 15 or 13%; Table 5.4). Three groups were seen to dive, all during seismic operations. Observers witnessed three occurrences of mating turtles (Table 5.4; Appendix I.1). Each mating observation occurred during seismic operations and precipitated a shut down. The coupling turtles (two pairs of olive ridley and one unidentified pair) were initially seen 200, 150, and 300 m from the observer station and got as close as 30, 35, and 101 m, respectively, to the GI guns after the guns had been shut down.

Summary and Conclusions

The number of "useable" sea turtle sightings recorded from the *Ewing* (n = 117), and the low proportion of these during non-seismic periods (n = 15), limits interpretation of behavior relative to seismic operations, and also limits comparisons between seismic and non-seismic periods. Sea turtle groups tended to be sighted farther from the GI guns during seismic than non-seismic conditions, although the few sightings when the larger GI guns were operating tended to be closer than those when the smaller GI guns were operating. Most sea turtles during both seismic and non-seismic operations were logging at the surface with variable orientations when first observed, and did not display any apparent avoidance behavior. Relatively few (8 or 8%) of the 102 turtles seen during seismic operations were actively moving away from the vessel, and five were moving toward the vessel. Three pairs of sea turtles were seen mating near the *Ewing* during seismic operations; none were seen mating during non-seismic periods.

A total of 71 shut downs and 16 power downs were implemented during the cruise because of sea turtles. All shut downs occurred when a turtle was first sighted within the 170 dB sound radii; there were no cases when a full shut down had been preceded by an initial power down. However, all of the observed turtles were seen at the water surface where the sound levels are much lower than those that would occur at the same radius deeper in the water (Appendix B.2). For that reason, along with the use of 170 dB radii appropriate to the larger GI guns even when the smaller guns were in use, many of the groups first sighted within the safety radii would not have been receiving ≥170 dB when seen. Ramp ups were interrupted four times because of the presence of sea turtles, and ramp ups had to be postponed on numerous occasions due to sea turtles within the safety radius.

The implementation of the 170 dB sound radius as a safety criterion for sea turtles was a precautionary measure given the limited available data regarding the effects of noise on sea turtles (see Chapter 3). Although the non-seismic sample size was small (n = 15), based on CPAs during seismic and non-seismic periods, the noise generated by the relatively small GI guns may have caused some sea turtles to move away from a small area around the approaching vessel during seismic operations.

The turtles observed during the ETPC survey were all "large" and appeared to be adult. We assume that a large number of hatchlings were present in the area, particularly near the known nesting sites, but were not observed and not the cause of any shut or power downs.

6. ACKNOWLEDGEMENTS

Lamont-Doherty Earth Observatory (L-DEO) and the National Science Foundation (NSF) provided the funding, and L-DEO provided the logistical support needed for the 2004 Eastern Tropical Pacific seismic survey off Central America (ETPCA) and the associated marine mammal and sea turtle monitoring program. We thank Michael Rawson and Dr. John Diebold of L-DEO, and Dr. Alexander Shor of NSF, for much assistance during planning and preparation for the cruise. Michael Rawson of L-DEO supervised the efforts to obtain and implement the incidental take authorization for the project. William E. Cross, Susan Dufault, and WRK of LGL were primarily responsible for preparing the IHA Application and an associated Environmental Assessment (EA).

The crew on the seismic source vessel R/V *Maurice Ewing* was extremely supportive of the marine mammal monitoring and mitigation effort. In particular, we acknowledge the assistance of Captain Mark C. Landow, Stanley P. Zeigler (Chief Mate), Richard N. Thomas (Second Mate), Robert J. Lyons, Jr. (Third Mate), Ted Koczynski (Science Officer and Technician), and Anthony D. Johnson (Computer Technician).

We thank the geophysics teams aboard the *Ewing* led by Drs. Craig Fulthorpe and Kirk McIntosh of the University of Texas Institute for Geophysics. The geophysics teams provided support and cooperation in obtaining data and implementing the marine mammal and sea turtle mitigation and monitoring program.

The vessel-based fieldwork was made possible by the dedicated participation of marine mammal and sea turtle observers Joseph Beland and Howie Goldstein (L-DEO), Alejandro Sayegh (CIC, Venezuela), along with lead bioacoustician Dr. Gianni Pavan (CIBRA, Italy), and the marine mammal team leader, MH (LGL).

We thank Mark Fitzgerald of LGL for helping to develop and implement procedures to estimate numbers of cetaceans that might have been exposed to seismic sounds, for assisting with processing and analyzing data, and for production of maps and figures. We also thank Dr. Gianni Pavan and Thomas Norris for contributions to the acoustic results section of the report. Dr. W. John Richardson, LGL's project director for the marine mammal and sea turtle monitoring, assisted at various stages during the planning, permitting, and fieldwork, and contributed to the draft report.

This work was conducted under an Incidental Harassment Authorization issued by the U.S. National Marine Fisheries Service (NMFS), Office of Protected Resources. We thank Ken Hollingshead, Nan Reck, and others of NMFS for processing the application, addressing the various agency and public comments, and working with L-DEO to define the expanded monitoring and mitigation requirements for this project. We also thank Michael Rawson and Dr. John Diebold of L-DEO and Dr. Alexander Shor of NSF for reviewing the initial application, EA, and (MR) this report.

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APPENDIX A:
INCIDENTAL HARASSMENT AUTHORIZATION

Incidental Harassment Authorization — Background Information

Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the MMPA. Such disturbance falls within the MMPA definition of Level B harassment, which entails "disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering". "Taking" of marine mammals without special authorization is prohibited. However, under the 1994 amendments to the MMPA and regulations released in 1996, "citizens of the United States can apply for an authorization to take incidentally, but not intentionally, small numbers of marine mammals by harassment" (NMFS 1996). IHAs can be issued if "taking will have a negligible impact on the species or stock(s) of marine mammals and will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses". IHAs can authorize unintentional harassment (disturbance) but not serious injury or mortality.

To minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries, IHAs issued to seismic operators call for a power down or shut down of the seismic source when marine mammals are seen within designated "safety radii". Under current NMFS guidelines, the safety radii around the arrays are customarily defined as the distances at which the received pulse levels diminish to 180 dB re 1 µPa (rms) for cetaceans and 190 dB for pinnipeds. The safety radii for this seismic study were predicted by L-DEO based on models of the sound pressure field around the applicable airgun configurations and on empirical calibration data collected by L-DEO in the Gulf of Mexico (Tolstoy et al. 2004a,b; Appendix C). The safety radii are further described in Chapter 3.

A verbatim copy (retyped) of the project IHA is presented below. However, the reference to the Northeastern Pacific Ocean off Oregon was incorrect in the IHA, and should be replaced by Eastern Tropical Pacific Ocean off Central America. Also, some of the mitigation and monitoring measures were modified during the cruise (with notification of NMFS) to make them more practical in the field. These changes are noted in the text below. Furthermore, the Incidental Take Statement (ITS) issued by NMFS in conjunction with this IHA included some additional conditions concerning sea turtles, and the ITS is included after the IHA.

Verbatim Copy of IHA for ETPCA Project

DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

Lamont-Doherty Earth Observatory, Columbia University, P.O. Box 1000, 61 Route 9W, Palisades, New York 10964-8000, is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1371 (a)(5)(D)) and 50 CFR 216.107, to harass small numbers of marine mammals incidental to conducting a marine seismic survey program in the Northeastern Pacific Ocean off Oregon[1], contingent upon the following conditions:

1. The Authorization is valid from the date of this Authorization through November 20, 2005.

2. This Authorization is valid only for activities associated with the *R/V Maurice Ewing* conducting a seismic survey program in the Eastern Tropical Pacific Ocean off Central America.

3. (a) The taking, by incidental harassment only, is limited to the species listed under condition 3(b) below. The taking by serious injury or death of these species or the taking by harassment, injury or death of any other species of marine mammal is prohibited and may result in the modification, suspension or revocation of this Authorization.

(b) The species authorized for incidental harassment takings are:

(*i*) Mysticete whales: humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), sei whale (*B. borealis*), fin whale (*B. physalus*), Bryde's whale (*B. edeni*), and blue whale (*B. musculus*);

(*ii*) Odontocete whales/dolphins: sperm whale (*Physeter macrocephalus*), dwarf sperm whale (*Kogia sima*), pygmy sperm whale (*K. breviceps*), Cuvier's beaked whale (*Ziphius cavirostris*), pygmy beaked whale (*Mesoplodon peruvianus*), Blainville's beaked whale (*M. densirostris*), rough-toothed dolphin (*Steno bredanensis*), bottlenose dolphin (*Tursiops truncatus*), pantropical spotted dolphin (*Stenella attenuata*), spinner dolphin (*S. longirostris*), striped dolphin (*S. coeruleoalba*), short-beaked common dolphin (*Delphinus delphis*), Fraser's dolphin (*Lagenodelphis hosei*), Risso's dolphin (*Grampus griseus*), melon-headed whale (*Peponocephala electra*), pygmy killer whale (*Feresa attenuata*), false killer whale (*Pseudorca crassidens*), killer whale (*Orcinus orca*), short-finned pilot whale (*Globicephala macrorhynchus*);

(*iii*) Pinnipeds: Galápagos sea lion (*Zalophus wollebaeki*), Galápagos fur seal (*Arctocephalus galapagoensis*), southern sea lion (*Otaria flavescens*), and South American fur seal (*A. australis*).

(c) The authorization for taking by harassment is limited to the following acoustic sources without an amendment to this Authorization:

(1) A seismic airgun array with no more than 3-General *[sic]* Injector (GI) GI guns operating;
(2) A multi-beam bathymetric sonar; and
(3) A sub-bottom profiler.

[1] This reference to Oregon is a holdover from a previous IHA.

(d) The taking of any marine mammal in a manner prohibited under this Authorization must be reported within 48 hours of the taking to the Chief of the Permits, Conservation and Education Division, Office of Protected Resources, National Marine Fisheries Service, at (301) 713-2289, ext 110, or his designee.

4. The holder of this Authorization is required to cooperate with the National Marine Fisheries Service and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals. The holder must notify the Chief of the Permits, Conservation and Education Division, Office of Protected Resources at least 48 hours prior to starting the seismic survey (unless constrained by the date of issuance of this Authorization in which case notification shall be made as soon as possible).

5. Mitigation. The holder of this Authorization is required to:

(a) (*i*) Establish and monitor the safety zone for cetaceans surrounding the 3-GI airgun array where the received level would be 180 dB re 1 μPa rms. This radius is estimated to be 82 m (269 ft) from the seismic source in water depths 1000 m (3281 ft) or greater, 123 m (403 ft) from the seismic source in water depths of 100-1000 m (328-3281 ft), and 574 m (1883 ft) in water depths less than 100 m (328 ft)[2];

(a) (*ii*) Establish and monitor the safety zone for pinnipeds surrounding the 3-GI airgun array where the received level would be 190 dB re 1 μPa rms. This radius is estimated to be 26 m (85 ft) from the seismic source in water depths 1000 m (3281 ft) or greater, 39 m (128 ft) from the seismic source in water depths of 100-1000 m (328-3281 ft), and 390 m (1280 ft) in water depths less than 100 m (328 ft);

(b) Immediately power-down or shut-down the seismic airgun array and/or other acoustic sources, whenever any marine mammals are sighted approaching close to or within the area delineated by the 180 dB (re 1 μPa_{rms}), or 190 dB (re 1 μPa_{rms}) isopleth as established under condition 5(a) for the 3 GI airgun array.

(c) During a power-down of the airgun array, if marine mammals enter or are about to enter the safety zone for the single remaining airgun that is firing, the remaining airgun will be immediately shut-down;

(*i*) A shut-down zone for the single GI-airgun for cetaceans is estimated to be 27 m (89 ft) from the seismic source in water depths 1000 m (3281 ft) or greater, 41 m (134 ft) from the seismic source in water depths of 100-1000 m (328-3281 ft), and 189 m (620 ft) in water depths less than 100 m (328 ft);

(*ii*) A shut-down zone for the single GI-airgun for pinnipeds is estimated to be 10 m (33 ft) from the seismic source in water depths 1000 m (3281 ft) or greater, 15 m (49 ft) from the seismic source in water depths of 100-1000 m (328-3281 ft), and 150 m (492 ft) in water depths less than 100 m (328 ft);

(d) Not proceed with powering up the 1-GI gun from a shut-down or the 3-GI airgun array from a power-down unless the entire safety zones described in condition 5(a) are visible and no marine mammals or sea turtles are detected within the appropriate safety zones; or until 15 minutes (for small odontocetes, pinnipeds) or a minimum of 30 minutes (for mysticetes/large odontocetes and sea turtles) after there has been no further visual detection of the animal(s) within the safety zone and the

[2] The safety radius for cetaceans was changed during the first few days of the cruise, with permission from NMFS, to account for the size of the airgun array to be used. The safety radii for the 315 in^3 array were 82, 123, and 574 m in deep, intermediate, and shallow water, respectively; the radii for the 135 in^3 array were 62, 93, and 433 m, respectively.

trained marine mammal observer on duty is confident that no marine mammals or sea turtles remain within the appropriate safety zone.

(e) Prior to commencing ramp-up described in condition 5(g), conduct a 30-minute period of observation by at least one trained marine mammal observer (*i*) at the commencement of seismic operations and (*ii*) at any time electrical power to the airgun array is discontinued for a period of 30 minutes or more.

(f) If the complete safety radii are not visible for at least 30 minutes prior to ramp-up in either daylight or nighttime, not commence ramp-up unless the seismic source has maintained a sound pressure level of at least 180 dB re 1 μPa rms during the interruption of seismic survey operations.

(g) If no marine mammals or sea turtles have been observed while undertaking mitigation condition 5(c), 5(d) and 5 (e), ramp-up airgun arrays no greater than 1 GI-airgun per 5-minute interval or approximately 6 dB per 5-minute period: (*i*) At the commencement of seismic operations, and (*ii*) anytime after the airgun array has been powered down for more than 4 minutes.

(h) (*i*) To the extent possible, run seismic lines from shallow water towards deeper water whether the lines are being run parallel to shore or perpendicular to shore; and

(*ii*) Reduce the volume of the airgun array during vessel turns while running seismic lines.

(i) To the extent practical, whenever a marine mammal is detected outside the safety radius, and based on its position and motion relative to the ship track is likely to enter the safety radius, an alternative ship speed or track will be calculated and implemented.

(j) Emergency shut-down. If observations are made or credible reports are received that one or more marine mammals or sea turtles are within the area of this activity in an injured or mortal state, or are indicating acute distress, the seismic airgun array will be immediately shut down and the Chief of the Permits, Conservation and Education Division, Office of Protected Resources or a staff member contacted. The airgun array will not be restarted until review and approval has been given by the Director, Office of Protected Resources or her designee.

(k) Use the SEAMAP Passive Acoustic Monitoring System to monitor for vocalizing marine mammals and to notify visual observers of nearby marine mammals. To the maximum extent possible, the SEAMAP system will be monitored continuously whenever the seismic airgun array is operating.

6. <u>Monitoring</u>

(a) The holder of this Authorization must designate at least four biologically-trained, on-site individuals to be onboard the *R/V Maurice Ewing*, approved in advance by the National Marine Fisheries Service, to conduct the visual and passive acoustic monitoring programs required under this Authorization and to record the effects of seismic surveys and the resulting noise on marine mammals and sea turtles.

(b) Monitoring is to be conducted by the biological observers described in condition 6(a) above, onboard the active seismic vessel. At least one observer must be on active watch whenever the seismic array is operating. To the maximum extent possible two observers will be on-watch whenever either of the seismic array is being powered up to (*i*) ensure that no marine mammals or sea turtles enter the appropriate safety zone whenever the seismic array is on, and (*ii*) to record marine mammal and sea turtle activity as described in condition 6(f) below.

(c) To the extent possible, observers will be on watch for continuous periods of 4 hours or less.

(d) At all times, the crew must be instructed to keep watch for marine mammals and sea turtles. If any are sighted, the bridge watch-stander must immediately notify the biological observer on-watch. If a marine mammal or sea turtle is within, or closely approaching, its designated safety zone, the airgun array must be immediately powered down.

(e) Observations by the biological observers described in condition 6(a) above on marine mammal presence and activity will begin a minimum of 30 minutes prior to the estimated time that the seismic source is to be turned on and/or ramped-up.

(f) Monitoring will consist of noting: (*i*) the species, group size, age/size/sex categories (if determinable), the general behavioral activity, heading (if consistent), bearing and distance from seismic vessel, sighting cue, behavioral pace, and apparent reaction of all marine mammals and sea turtles seen near the seismic vessel and/or its airgun array (e.g., none, avoidance, approach, paralleling, etc) and; (*ii*) the time, location, heading, speed, and activity of the vessel (shooting or not), along with sea state, visibility, cloud cover and sun glare at (1) any time a marine mammal or sea turtle is sighted, (2) at the start and end of each watch, and (3) during a watch (whenever there is a change in one or more variable); and, (*iii*) the identification of all vessels that are visible within 5 km of the seismic vessel whenever a marine mammal is sighted, and the time observed, bearing, distance, heading, speed and activity of the other vessel(s).

(g) Biological observers will also conduct monitoring onboard the *R/V Maurice Ewing* while the seismic array is being deployed or being pulled from the water.

(h) All biological observers must be provided with and use appropriate night-vision devices, Big Eyes, and reticulated and/or laser range finding binoculars.

7. Reporting

(a) A draft report will be submitted to the National Marine Fisheries Service within 90 days after the end of the seismic survey program in the Eastern Tropical Pacific Ocean. The report will describe in detail (*i*) the operations that were conducted, (*ii*) the marine mammals and sea turtles that were detected near the operations, (*iii*) to the extent possible the results of the acoustical measurements to verify the safety radii,[3] and (*iv*) the methods, results, and interpretation pertaining to all monitoring tasks, a summary of the dates and locations of seismic operations, sound measurement data, marine mammal and sea turtle sightings (dates, times, locations, activities, associated seismic survey activities), and estimates of the amount and nature of potential take of marine mammals by harassment or in other ways.

(b) The 90-day draft report will be subject to review and comment by the National Marine Fisheries Service. Any recommendations made by the National Marine Fisheries Service must be addressed in the final report prior to acceptance by the National Marine Fisheries Service. The draft report will be considered the final report for this activity under this Authorization if the National Marine Fisheries Service has not provided comments and recommendations within 90 days of receipt of the draft report.

8. Activities related to the monitoring described in this Authorization do not require a separate scientific research permit issued under section 104 of the Marine Mammal Protection Act.

9. The holder of this Authorization is required to fully implement and Terms and Conditions contained in the Biological Opinion issued by the National Marine Fisheries Service for this activity.

10. A copy of this Authorization must be in the possession of the operator of the vessel operating under the authority of this Incidental Harassment Authorization.

Date: Nov 17 2004

[3] Acoustical measurements were conducted during an earlier L-DEO cruise (Tolstoy et al. 2004a,b), but were not planned or conducted during this ETPCA cruise.

Terms and Conditions of the Incidental Take Statement[4]

The Incidental Take Statement identified additional required mitigation and monitoring measures, as follows:

1. Enlarge the safety zone for sea turtles to include the 170 dB isopleth and follow the IHA

2. Increase the nighttime observer coverage to equal or exceed the daytime observer coverage

3. Not proceed with powering up the 1-GI gun from a shut-down or the 3-GI airgun array from a power-down unless the entire safety zones described in IHA condition 5(a) are visible and no marine mammals or sea turtles are detected within the appropriate safety zones; or until 15 minutes (for small odontocetes, pinnipeds) or a minimum of 30 minutes (for mysticetes/large odontocetes or sea turtles) after there has been no further visual detection of the animal(s) within the safety zone and the trained marine mammal observer on duty is confident that no marine mammals or sea turtles remain within the appropriate safety zone.

4. The operator of each vessel operating under the authority of this Incidental Harassment Authorization must ensure that the mitigation, monitoring, and reporting conditions contained in the IHA are implemented.

5. Monitor implementation and effectiveness of all conservation measures described in the proposed project and the aforementioned Reasonable and Prudent Measures and these accompanying Terms and Conditions and include this information in report submitted by the applicant.

6. A copy of the Incidental Take Statement and IHA must be in the possession of the operator of each vessel operating under the authority of this IHA.

7. PCED must ensure that the Endangered Species Division is immediately informed of any changes or deletions to any portions of the monitoring plan or IHA.

8. PCED must ensure that the report submitted by the applicant be provided to the Endangered Species Division after completion of the work described in the IHA.

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[4] Taken verbatim from the Incidental Take Statement (ITS). Some of the mitigation and monitoring measures were changed during the cruise (with notification of NMFS) to make them more practical in the field. ***Condition 2*** was required only during surveys of areas near sea turtle nesting beaches (the two southernmost study areas) and in the Gulf of Fonseca. ***Condition 3*** was amended after it became apparent that shut downs for sea turtles were very frequent, and the 15- or 30-min periods that were required before the array could be ramped up again were resulting in great loss of seismic data. Given the speed of the ship, the 15-min and especially 30-min periods were quite conservative. The turtle would be outside the safety radius in much less than 30 min after the sighting. Consequently, this period was reduced to 4 min in intermediate and deep water (>100 m deep) and 10 min in shallow water (<100 m deep).

APPENDIX B:
DEVELOPMENT AND IMPLEMENTATION OF SAFETY RADII

This appendix provides additional background information on the development and implementation of safety radii by NMFS as relevant to the L-DEO seismic study discussed in this report. Additional information on L-DEO's calibration study conducted with various configurations of the *Ewing*'s airgun arrays is also provided. Further information on these topics can be found in Smultea and Holst (2003), Tolstoy (2004a,b), and the project IHA application and EA (LGL 2004a,b).

It is not known whether exposure to a sequence of strong pulses of low-frequency underwater sound from marine seismic exploration actually can cause hearing impairment or non-auditory injuries in marine mammals (Richardson et al. 1995:372*ff*; Finneran et al. 2002). There has been considerable speculation about the potential for injury to marine mammals, based primarily on what is known about hearing impairment to humans and other terrestrial mammals exposed to impulsive low-frequency airborne sounds (e.g., artillery noise). The 180-dB criterion for cetaceans was established by NMFS (1995) based on those considerations, before any data were available on temporary threshold shift (TTS) in marine mammals. NMFS (1995, 2000) concluded that there are unlikely to be any physically-injurious effects on cetaceans exposed to received levels of seismic pulses up to 180 dB re 1 μPa (rms). The corresponding NMFS criterion for pinnipeds is 190 dB re 1 μPa (rms).

Finneran et al. (2002) have found that the onset of mild Temporary Threshold Shift (TTS) in a beluga whale (odontocete) exposed to a single watergun pulse occurred at a received level of 226 dB re 1 μPa pk-pk and a total energy flux density of 186 dB re 1 $\mu Pa^2 \cdot s$. The corresponding rms value for TTS onset upon exposure to a single watergun pulse would be intermediate between these values. It is assumed (though data are lacking) that TTS onset would occur at lower received levels if the animals received a series of pulses. However, no specific results confirming this are available yet. On the other hand, the levels necessary to cause injury would exceed, by an uncertain degree, the levels eliciting TTS onset.

The above-mentioned 180 dB re 1 μPa level is measured on a root mean square (rms) basis. The rms (root-mean-square) pressure is an average over the seismic pulse duration of the seismic pulse (Greene 1997; Greene et al. 1998). This is the measure commonly used in recent studies of marine mammal reactions to airgun sounds. The rms level of a seismic pulse is typically about 10 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000a). Rms level is affected by duration of the received pulse, which depends on propagation effects between the source and the receiving animal. The greater the temporal dispersion of (i.e., the longer) the received pulse, the lower the expected rms level. Biological effects probably are more closely related to energy content of the received pulse than to its rms pressure, but we consider rms pressure because current NMFS criteria are based on that method.

Radii within which received levels were expected to diminish to various values relevant to NMFS criteria mentioned above were determined by L-DEO based on a combination of acoustic modeling and empirical measurements. • Empirical data were obtained by Tolstoy et al. (2004a,b) for sounds from two 105 in^3 (generator volume) GI guns, a 20-airgun array (the largest array deployed from the *Ewing*), and various intermediate-sized airgun arrays. (The calibration study did not include the specific 3-GI-gun array subsequently used in the Nov.–Dec. 2004 ETPCA study.) The empirical data were collected in the Gulf of Mexico from 27 May to 3 June 2003, with separate measurements in deep and shallow water (Tolstoy et al. 2004a,b). • The rms received levels in the near field around various airgun configurations used by L-DEO have been predicted based on an L-DEO model. Figures B.1 and B.2, below, show examples, including (in

Fig. B.2) the prediction for the 3-GI-gun source. These estimates pertain primarily to deep water, as the model does not allow for bottom interactions.

For mitigation purposes during this and other recent L-DEO studies, three strata of water depth were distinguished: deep (>1000 m), intermediate (100–1000 m), and shallow (<100 m). The calibration study showed that sounds from L-DEO's larger airgun sources (i.e., 6–20 airguns) operating in deep water tend to have lower received levels than estimated by the model. In other words, the model tends to overestimate the actual 180 dB, 160 dB, etc., radii in deep water (Tolstoy et al. 2004a,b). Conversely, in shallow water, the model substantially underestimates the actual measured radii for various source configurations ranging from 2 to 20 airguns. More specifically, the primary conclusions of L-DEO's calibration study relevant to this and other recent projects are summarized below:

- The empirical data indicated that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004a,b). However, pending acquisition of additional empirical data, the estimated radii during airgun operations in deep water during all 2004 L-DEO cruises were predicted by L-DEO's model (Table 4.8).
- The 180- and 190-dB radii were not measured for small sources operating in ***shallow water*** (<100 m). However, the measured 180-dB radius for the 6-airgun array operating in shallow water was 6.8× that predicted by L-DEO's model for operation of the 6-airgun array in deep water. This correction factor was applied to the model estimates to predict the radii for the 3 GI guns in shallow water (Table 4.8 and Fig. B.2).
- Empirical measurements were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results would be intermediate between those from shallow and deep water, a 1.5× correction factor was applied to the estimates provided by the model for deep water situations (Table 4.8). This is the same factor that was applied to all the model estimates during L-DEO cruises in 2003, and to the estimates for intermediate-depth water during all 2004 cruises.

For sea turtles, the Incidental Take Statement issued by NMFS for the project specified that the 170d dB radius should be taken as the safety radius (see Appendix A). This was a non-standard requirement. The 170 dB radii appropriate to each configuration of GI guns and each water depth stratum were estimated via the same procedures as used to estimate the 180 and 190 dB radii.

The radius at which received levels diminish to 160 dB re 1 μPa (rms) is considered by NMFS to be a possible criterion of behavioral disturbance (not a safety radius). The data on which this 160 dB criterion is based pertain to baleen whales, and many of the odontocetes (e.g., delphinids) do not appear to be as responsive to seismic sounds as are baleen whales (Richardson et al. 1995; Gordon et al. 2004). In this report, the numbers of all species exposed to ≥160 dB are estimated. However, for certain taxa (e.g., delphinids), the 170 dB radius is considered as an alternative and more realistic estimate of the outer bounds of the area within which animals are likely to be disturbed significantly. For those taxa, the numbers exposed to ≥170 dB are also estimated.

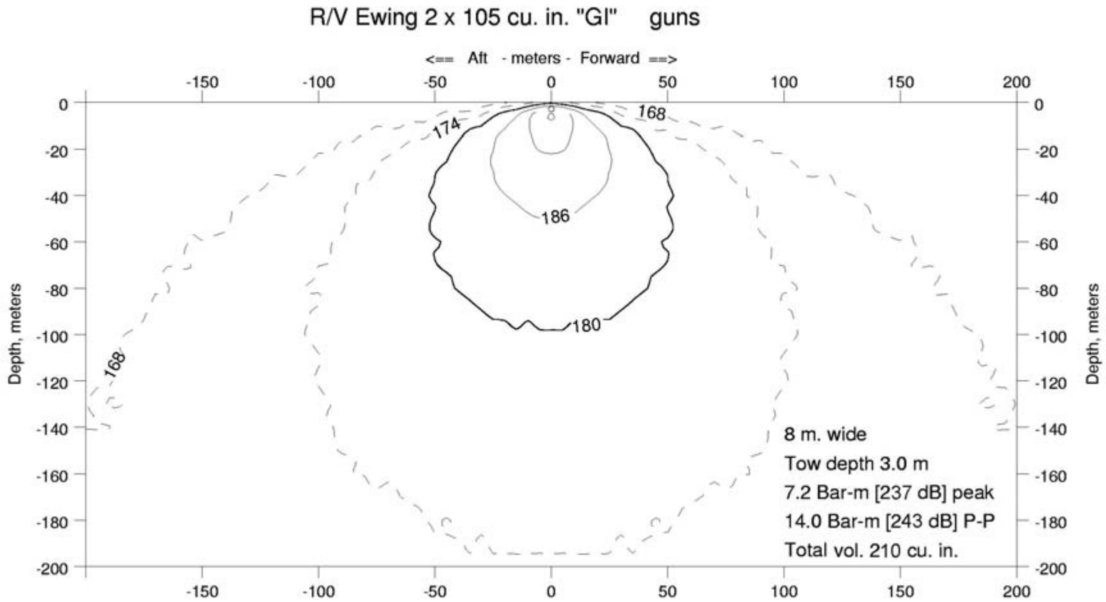

FIGURE B.1. Predicted received sound levels (dB re 1 µPa, rms) in deep water from the two 105 in^3 GI guns (total generator volume 210 in^3) used during a small portion (1%) of the ETPCA survey, 21 Nov.–22 Dec. 2004. For most (75%) of the ETPCA seismic survey periods, three 45 in^3 GI guns (total volume 135 in^3) were used.

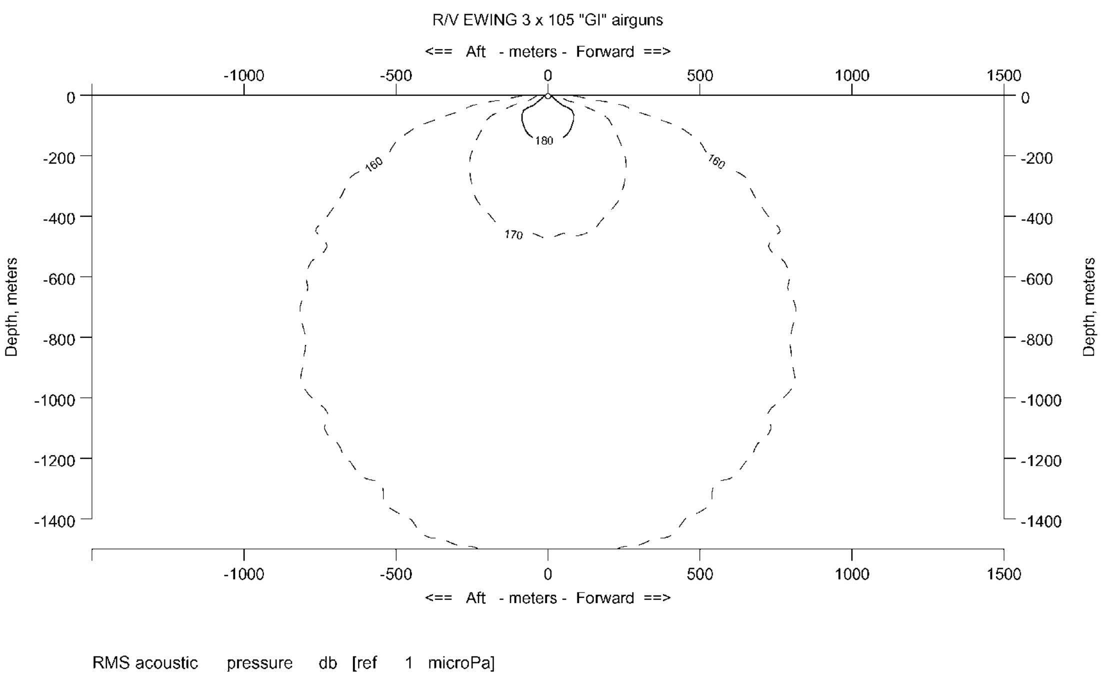

FIGURE B.2. Modeled received sound levels from the three 105 in^3 GI guns (total generator volume 315 in^3) used during some (9%) of the seismic periods during the ETPCA survey 21 Nov. – 22 Dec. 2004. The three 45 in^3 GI guns (total volume 135 in^3) were used during the majority (75%) of the seismic periods during the ETPCA survey.

APPENDIX C: DESCRIPTION OF R/V *MAURICE EWING* AND EQUIPMENT USED DURING THE PROJECT

This appendix provides a detailed description of the standard equipment used during this and previous L-DEO seismic studies aboard the *Ewing*.

R/V Maurice Ewing Vessel Specifications

L-DEO used the R/V *Maurice Ewing* for the seismic study to tow the airgun array and hydrophone streamer (Fig. C.1, C.2). The *Ewing* was self-contained, with the crew living aboard the vessel. The *Ewing* has a length of 70 m (230 ft), a beam of 14.1 m (46.3 ft), and a draft of 4.4 m (14.4 ft). The *Ewing* has four 1000-kW diesel generators that supply power to the ship. The ship is powered by four 800-hp electric motors that, in combination, drive a single 5-blade propeller in a Kort nozzle and a single-tunnel electric bow thruster rated at 500 hp. At the typical operation speed of 7.4–9.3 km/h (4–5 knots) during seismic acquisition, the shaft rotation speed is about 90 rpm. When not towing seismic survey gear, the *Ewing* cruises at 18.5–20.4 km/h (10–11 knots) and has a maximum speed of 25 km/h (13.5 knots). It has a normal operating range of about 31,500 km (17,000 n.mi.). The maneuverability of the vessel was limited during operations, due to the presence of the streamer and airgun array behind the vessel.

Other details of the *Ewing* include the following:

Owner:	National Science Foundation
Operator:	Lamont-Doherty Earth Observatory of Columbia University
Flag:	United States of America
Date Built:	1983 (modified in 1990)
Gross Tonnage:	1978
Fathometers:	3.5 and 12 kHz hull-mounted transducers; Furuno FGG80 echosounder; Furuno FCU66 echosounder recorder
Bottom Mapping Equipment:	Atlas Hydrosweep DS-2, 15.5 kHz multi-beam bathymetric (MBB) sonar: details below
Compressors for Airguns:	LMF DC, capable of 1000 standard cubic feet per minute (scfm) at 2000 psi
Accommodation Capacity:	21 crew plus 3 technicians and 26 scientists

The *Ewing* also served as a platform from which vessel-based MMOs watched for marine mammals and sea turtles. The flying bridge was the best vantage point and afforded good visibility for the observers (Fig. C.1). However, visibility immediately astern of the *Ewing* was slightly restricted because of intervening superstructures (Fig. C.3, C.4). L-DEO constructed an MMO station with an overhead structural canopy on the flying bridge for shelter from sun, wind, and rain (Fig. C.5).

FIGURE C.1. The source vessel, the R/V *Maurice Ewing,* showing the location of the flying bridge from which visual observations were made by the marine mammal and sea turtle observers.

FIGURE C.2. Two GI guns deployed from the fantail of the R/V *Maurice Ewing* during L-DEO's SE Alaska seismic cruise during summer 2004. The same method was used to deploy 3 GI guns during the Nov.–Dec. 2004 ETPCA seismic cruise from aboard the *Ewing.* The starboard gun is fully deployed; the port gun is being pulled in. The streamer can be seen extending off the stern.

filename:StarboardProfile&AfterSection(revised)

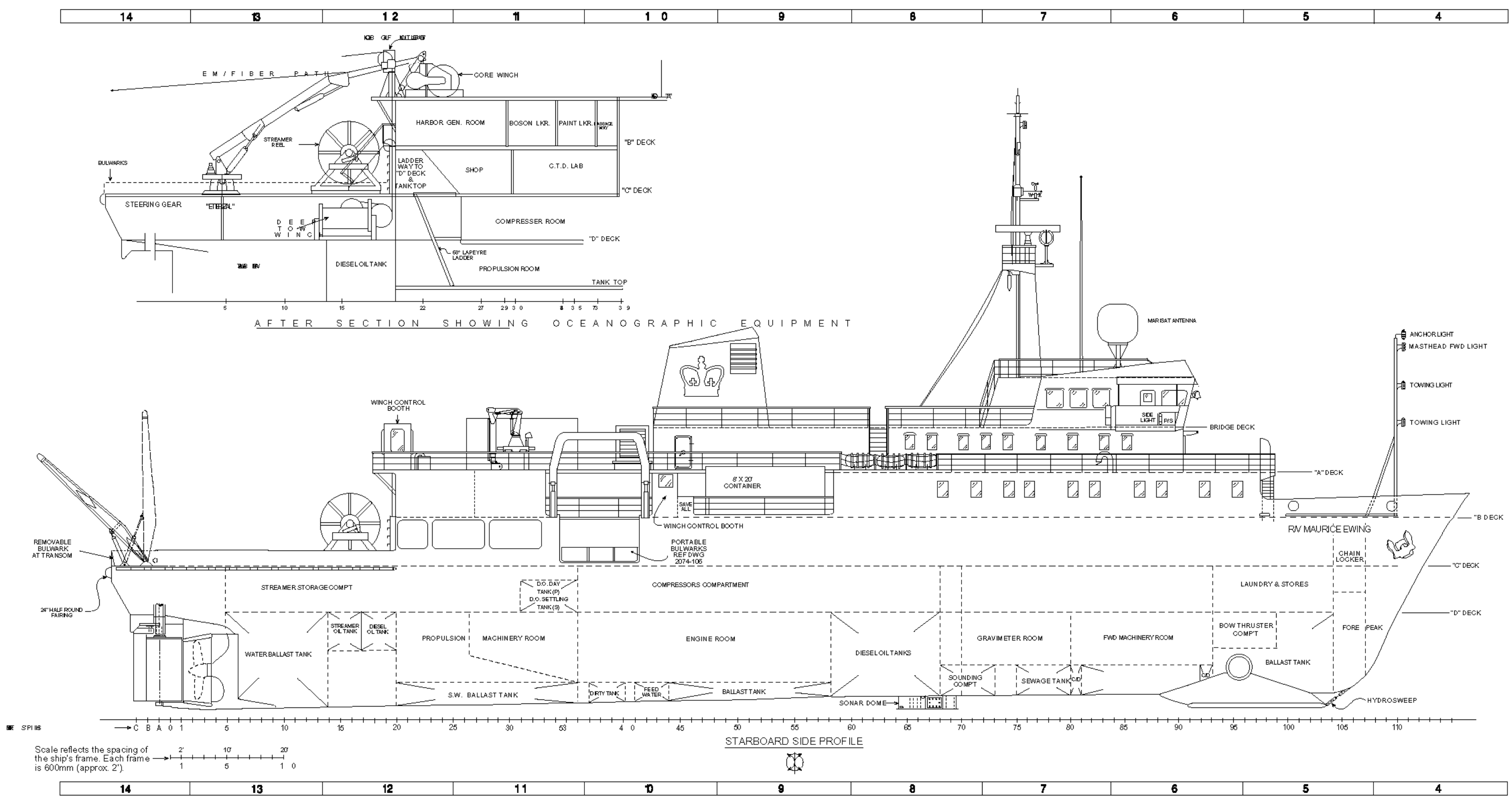

FIGURE C.3. Schematic starboard profile of the R/V *Maurice Ewing*.

FIGURE C.4. A view looking toward the stern from the center of the visual observer station on the flying bridge of the *Ewing*, showing the ship structures (two support structures and, at center, a smokestack) that partially block the view to the stern. The partial obstruction is considerably reduced when two observers are stationed on opposite sides of the flying bridge.

FIGURE C.5. A view of the flying bridge of the *Ewing* showing the visual observer station and associated equipment, including two mounted pairs of 25×150 "Big-eyes" binoculars used during the study.

Multi-beam Sonar, Sub-bottom Profiler, and Echosounder

Along with the airgun operations, an Atlas Hydrosweep DS-2 multibeam 15.5-kHz bathymetric sonar and a 3.5 kHz sub-bottom profiler were used by the geophysical science party to map the bathymetry to meet the project's scientific goals. While the *Ewing* was in the seismic study area, these two sources typically operated simultaneously with the seismic source. The two systems are mounted on the hull of the *Ewing* (Fig. C.3).

The ***Atlas Hydrosweep*** is specialized for mapping the bathymetry at deep (>500 m) water depths. However, it can operate in three modes, depending on the water depth. It has one shallow-water mode and two deep-water modes: an Omni mode and a Rotational Directional Transmission (RDT) mode. When water depth is <400 m, the shallow-water mode is used. The source output is 210 dB re 1 µPa · m rms and a single 1-millisecond pulse or "ping" per second is transmitted, with a beamwidth of 2.67º fore-aft and 90º athwartship. The beamwidth is measured to the –3 dB point, as is usually quoted for sonars. The Omni mode is identical to the shallow-water mode except that the source output is 220 dB re 1 µPa · m. The Omni mode is normally used only during start up. In the RDT mode, each "ping" consists of five successive transmissions, each ensonifying a beam that extends 2.67º fore-aft, and ~30º athwartships. The five successive transmissions (segments) sweep from port to starboard with minor overlap, spanning an overall cross-track angular extent of ~140º, with tiny (<<1 ms) gaps between the pulses for successive 30º segments. The total duration of the "ping", including all 5 successive segments, varies with water depth but is 1 ms in water depths <500 m and 10 ms in the deepest water. For each segment, ping duration is 1/5th of these values or 2/5th for a receiver in the overlap area ensonified by two beam segments. The "ping" interval during RDT operations depends on water depth and varies from once per second in <500 m water depth to once per 15 seconds in the deepest water.

The 3.5 kHz ***sub-bottom profiler*** is normally operated from aboard the *Ewing* to provide information about the sedimentary features and the bottom topography that is simultaneously being mapped by the Hydrosweep. The maximum source output (800 watts) of the sub-bottom profiler is 204 dB re 1 µPa, and the normal (500 watts) source output is 200 dB re 1 µPa. The energy from the sub-bottom profiler is directed downward by a 3.5 kHz transducer mounted in the hull of the *Ewing*. The output varies with water depth from 50 watts in shallow water to 800 watts in deep water. Pulse interval is 1 s but a common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

The *Ewing*'s two standard vessel ***echosounders*** (i.e., fathometers) were the only other sonars operated during the cruise: a Furuno FGG80 echosounder and a Furuno FCU66 echosounder recorder. These two systems were operated only to provide additional information on water depths for navigational safety purposes while traversing poorly-charted areas or while in and near ports. These general types of echosounders are standard equipment for large vessels.

APPENDIX D:
DETAILS OF MONITORING, MITIGATION, AND ANALYSIS METHODS

This appendix provides details on the standard visual and acoustic monitoring methods and data analysis techniques implemented for this project and previous L-DEO seismic studies from aboard the *Ewing*.

Résumés documenting the qualifications of the MMOs were provided to NMFS prior to commencement of the study. All MMOs participated in a review meeting before the start of the study, designed to familiarize them with the operational procedures and conditions for the cruise, reporting protocols, and IHA and ITS stipulations. In addition, implementation of the IHA and ITS requirements was explained to the Captain, Science Officer, and Science Party PIs aboard the vessel. MMO duties included

- watching for and identifying marine mammals and sea turtles, and recording their numbers, distances and behavior;
- noting possible reactions of marine mammals and sea turtles to the seismic operations;
- initiating mitigation measures when appropriate; and
- reporting the results.

Visual Monitoring Methods

Visual watches took place in the seismic survey area and during transits to and from the study area. In addition to conducting watches during seismic operations, MMOs also conducted daytime watches when the source vessel was underway but the airguns were not firing. This included ***(1)*** periods during transit to and from the seismic survey area, ***(2)*** a short "pre-seismic period" while equipment was being deployed, ***(3)*** periods when the seismic source stopped firing while equipment was being repaired, and ***(4)*** a short "post-seismic" period.

Visual observations were generally made from the *Ewing*'s flying bridge (Figs. C.1, C.5), the highest suitable vantage point on the *Ewing*. The observer's eye level was ~14.5 m (47 ft) above sea level. The flying bridge afforded a view of ~320º centered on the front of the *Ewing*, with partial obstructions to the stern (Fig. C.4). With two or more observers, one stationed on the port and one on the starboard side of the vessel, the partial obstruction was reduced to some extent. MMOs observed from the *Ewing*'s bridge during periods of poor weather. The observer's eye level on the bridge was ~11.7 m (38 ft) above sea level, with a field of view of ~135º.

A total of five biologically-trained observers were present on the *Ewing* during the ETPCA study. Visual watches aboard the *Ewing* were usually conducted in 1–2 h shifts (max. 4 h), alternating with PAM shifts and/or 1–4 h breaks, for a total of 10 h per day per MMO during full operational days. Daytime watches were conducted from dawn until dusk. MMO(s) scanned around the vessel, alternating between unaided eyes and 7×50 Fujinon binoculars. Occasionally scans were also made using the 25 × 150 Big-eye binoculars, to detect animals and to identify species or group size during sightings. Both the Fujinon and Big-eye binoculars were equipped with reticles on the ocular lens to measure depression angles relative to the horizon, an indicator of distance. During the day, at least one and if possible two MMOs were on duty, especially during the 30 min before and during ramp ups.

In addition to daytime observations, nighttime observations were also required during certain periods, including during ramp up of the airgun array at night and (for the ETPCA study) when near sea turtle nesting areas (see Chapter 3). The former is a typical requirement of IHAs for L-DEO seismic cruises. The latter was a special requirement of the this study. Image intensifying Night Vision Devices (NVDs, ITT Industries Night

Quest NQ220 "Night Vision Viewer") were used during nighttime observations, although previous experience has shown that marine mammals are rarely detected at night even with the use of such devices. Nonetheless, they do provide some observation capability at close distances at night, up to ~100–250 m (see Smultea and Holst 2003; Holst 2004; Smultea et al. 2004; MacLean and Koski 2005). For example, a total of five cetacean groups and one sea turtle have been seen at night by MMOs using NVDs aboard the *Ewing*. These sightings include one group initially heard and then seen with the NVDs during the fall 2004 Gulf of Alaska seismic survey (MacLean and Koski 2005), and two delphinid groups first seen with the NVDs during the ETPCA cruise described herein. Only one MMO was on watch during the night, although two MMOs were typically present for 30 min before as well as during all ramp ups. During the night, observations by MMOs ceased after the completion of the ramp up if the operations were taking place outside of turtle nesting areas, but continued all night if seismic operations were occurring near nesting beaches.

When MMO(s) were not on active duty at night, the *Ewing* bridge personnel were asked to watch for marine mammals and turtles during their regular watches. They were provided with a copy of the observer instruction manual and marine mammal identification guides that were kept on the bridge. If bridge crew sighted marine mammals or sea turtles while the airguns were operating and no MMO was present, they were asked to implement power- or shut-down provisions when required. They were given instructions on how to fill out specific marine mammal and sea turtle sighting forms in order to collect pertinent information on any sightings when MMOs were not on active duty. Bridge personnel would also keep watch for marine mammals and turtles during the day, when MMO(s) were on duty.

While on watch, visual observers kept systematic written records of the vessel's position and activity, and environmental conditions. Codes that were used for this information are shown in Table D.1. Watch data were entered manually onto a datasheet every ~30 min, as activities allowed. Additional data were recorded when marine mammals or sea turtles were observed. For all records, the date and time (in GMT), vessel position (latitude, longitude), and environmental conditions were recorded. Environmental conditions also were recorded whenever they changed, and with each sighting record. Standardized codes were used for the records, and written comments were usually added as well.

For each sighting, the following information was recorded: species, number of individuals seen, direction of movement relative to the vessel, vessel position and activity, sighting cue, behavior when first sighted, behavior after initial sighting, heading (relative to vessel), bearing (relative to vessel), distance, behavioral pace, species identification reliability, and environmental conditions. Codes that were used to record this information during the cruise are shown in Table D.1. Distances to groups were estimated from the MMO station on the flying bridge, rather than from the nominal center of the seismic source (the distance from the sighting to the airguns was calculated later during analyses). However, for sightings near or within the safety radius in effect at the time, the distance from the sighting to the nearest airgun was estimated and recorded for the purposes of implementing power down or shut down mitigation. The bearing from the observation vessel to the nearest member of the group was estimated using positions on a clock face, with the bow of the vessel taken to be "12 o'clock", and the stern at 6 o'clock.

Operational activities that were recorded by MMOs included the number of airguns in use, total volume of the airguns in use, and type of vessel/seismic activity. Vessel position and airgun activity (number and total volume of airguns) were available from a monitor on the *Ewing* flying bridge. That monitor was connected to the bridge navigational display monitor. The position of the vessel was automatically logged every minute by the *Ewing's* navigation system. Those data were used when detailed position information was required. In addition, the following information was recorded for other vessels within 5 km (as specified in the IHA) at the time of a marine mammal sighting: vessel type, size, heading (relative to study vessel), bearing (relative to study vessel), distance, and activity. Inter-ship phone communication with the geophysicists and the MMO conducting PAM (in the ship's dry laboratory) was used to alert the visual MMOs to any changes in operations, and any marine mammals detected acoustically.

All data were initially recorded on custom paper datasheets in the field, and were entered into a Microsoft Excel® database at the end of the day. The database was constructed to prevent entry of out-of-range values and codes. Data entries were checked manually by comparing listings of the computerized data with the original handwritten datasheets, both in the field and upon later analyses. Data collected by the MMOs were also checked against the navigation and shot logs collected automatically by the vessel's computers, and manually against the geologists' project logs.

Passive Acoustic Monitoring Methods

Passive acoustic monitoring was conducted from aboard the *Ewing* to detect calling cetaceans and to alert visual MMOs to the presence of these animals. SEAMAP is the standard system typically used for PAM during L-DEO's seismic cruises. The SEAMAP system consists of hardware (i.e., the hydrophone) and the software program. The "wet end" of the SEAMAP system consists of a low-noise, towed hydrophone array that is connected to the vessel by a "hairy" faired cable. During this cruise, the array was deployed from a winch located on the back deck. A deck cable was connected from the winch to the main computer lab where the SEAMAP and signal conditioning and processing system were located.

The hydrophone array was 56 m in length and consisted of an active section of four hydrophones. The distance between the outer hydrophones was ~50 m. Only two hydrophones were monitored simultaneously with the SEAMAP system: either the outer two hydrophones or two hydrophones spaced 44.4 m apart. This separation distance is suitable for determining bearings, if possible, to most types of cetacean sounds (SEAMAP 2003). The length of the lead-in cable to the array was ~300 m and generally was fully deployed when the system was in use. The depth at which the hydrophone array was towed can be adjusted by adding or removing weights. During the ETPCA cruise, the array was towed at a depth of ~20 m.

Due to numerous problems with the SEAMAP software, a back-up software and recording system (SeaProUltra designed by CIBRA, University of Pavia, Italy) was usually used during the ETPCA cruise. Details of the SEAMAP system and monitoring protocol are given below, followed by details about the CIBRA back-up system that was mainly used for recording of vocalizations during the cruise. The SEAMAP system (as well as the CIBRA system) was used to display the incoming signals on the monitor, but it could not be used to record or localize vocalizations. The CIBRA system was used to record vocalizations, but it was not capable of localizing vocalizations.

SEAMAP

SEAMAP software (version 1.525, Houston, TX) can be used for real-time processing of two channels of acoustic data from the array. GPS position is recorded automatically by SEAMAP software every minute. Integrated plotting software automatically displays the ship location, as well as a user-defined safety radius, graphically depicted as a colored ring centered on the airgun array. Waveform, spectral density, and a sound spectrogram are displayed using the SEAMAP software. Cross-correlation techniques are used to calculate the time delay between the signals arriving at two hydrophones in the SEAMAP array. A signal of interest (e.g., any signal believed to be a cetacean call) can be selected by the operator with a mouse using a "windowing" feature. The speed of sound, the time delay, and the distance between the two hydrophones are used to calculate the bearing to the selected signal. The bearing to the signal is graphically displayed on the plot display in SEAMAP.

TABLE D.1. Summary of data codes used during the seismic survey cruise in the Eastern Tropical Pacific Ocean Nov.-Dec. 2004.

WS	Watch Start
WE	Watch End
LINE	
Enter Line ID or leave blank	
SEISMIC ACTIVITY	
RU	Ramp-up
LS	Line Shooting
SH	Shooting Between/Off.Lines
ST	Seismic Testing
SZ	Safety Zone Shut-Down
PD	Power-Down
SD	Shut-Down
OT	Other (comment and describe)
# GUNS	
Enter Number of Operating Airguns, or	
88	Varying (e.g., ramp-up)
99	Unknown
ARRAY VOLUME	
Enter operating volume, or	
99	Unknown
(BEAUFORT) SEA STATE	
See Beaufort Scale sheet.	
LIGHT OR DARK	
L	Light (day)
D	Darkness
GLARE AMOUNT	
NO	None
LI	Little
MO	Moderate
SE	Severe
POSITION	
Clock Position, or	
99	Variable (vessel turning)
WATER DEPTH	
In meters	
MARINE MAMMAL SPECIES	
Baleen Whales	
BLW	Blue Whale
BRW	Bryde's Whale
FW	Fin Whale
SW	Sei Whale
HW	Humpback Whale
MW	Minke Whale
UMW	Unidentified Mysticete Whale
UW	Unidentified Whale
Large Toothed Whales	
DSW	Dwarf Sperm Whale
FKW	False Killer Whale
KW	Killer Whale
LFPW	Long-finned Pilot Whale
MHW	Melon-headed Whale
PKW	Pygmy Killer Whale
PSW	Pygmy Sperm Whale
SPW	Sperm Whale
SFPW	Short-finned Pilot Whale
UTW	Unidentified Tooth Whale
Beaked Whales	
BAW	Baird's Beaked Whale
BLW	Blainville's Beaked Whale
CBW	Cuvier's Beaked Whale
TBW	Gingko-toothed Beaked Whale
LBW	Longman's Beaked Whale
PBW	Pygmy Beaked Whale
UBW	Unidentified Beaked Whale
Dolphins	
BD	Bottlenose Dolphin
DD	Dusky's Dolphin
FD	Fraser's Dolphin
LCD	Unidentified common dolphin
PSP	Pantropical Spotted Dolphin
RD	Risso's Dolphin
RTD	Rough-toothed Dolphin
SCD	Short-beaked Common Dolphin
SPD	Spinner Dolphin
SRD	Southern Right Whale Dolphin
STD	Striped Dolphin
UD	Unidentified Dolphin
Porpoise	
HP	Harbor Porpoise
DP	Dall's Porpoise
BP	Burmeister's Porpoise
Pinnipeds	
CSL	California Sea Lion
HBS	Harbor Seal
HDS	Hooded Seal
NES	Northern Elephant Seal
NFS	Northern Fur Seal
SSL	Steller Sea Lion
US	Unidentified Seal
TURTLE SPECIES	
GR	Green Turtle
LH	Loggerhead Turtle
LB	Leatherback Turtle
OR	Olive Ridley Turtle
UT	Unidentified Turtle
MOVEMENT	
ST	Swim Toward
SA	Swim Away
FL	Flee
SP	Swim Parallel
MI	Mill
NO	No movement
UN	Unknown
INDIVIDUAL BEHAVIOR	
SI	Sink
FD	Front Dive
TH	Thrash Dive
DI	Dive
LO	Look
LG	Logging
SW	Swim
BR	Breach
LT	Lobtail
SH	Spyhop
FS	Flipper Slap
FE	Feeding
FL	Fluking
BL	Blow
BO	Bow Riding
PO	Porpoising
RA	Rafting
WR	Wake Riding
AG	Approaching Guns
DE	Dead
OT	Other (describe)
NO	None (sign seen only)
UN	Unknown
GROUP BEHAVIOR (BEHAVIORAL STATES)	
TR	Travel
SA	Surface Active
ST	Surface Active-Travel
MI	Milling
FG	Feeding
RE	Resting
OT	Other (describe)
UN	Unknown
# RETICLES or ESTIMATE	
(of Initial Distance, etc.; Indicate Big eyes or Fujinons in comments)	
0 to 16	Number of reticles
E	Estimate, by eye
SIGHTING CUE	
BO	Body
HE	Head
SP	Splash
FL	Flukes
DO	Dorsal Fin
BL	Blow
BI	Birds
IDENTIFICATION RELIABILITY	
MA	Maybe
PR	Probably
PO	Positive
BEHAVIOR PACE	
SE	Sedate
MO	Moderate
VI	Vigorous
WITH ABOVE RECORD?	
Y	Yes
(blank)	not with above record

SEAMAP uses cross-correlation techniques, as applied to the waveforms from two SEAMAP hydrophones, to estimate the bearing to the marine mammal in real-time. The arrival times of the sound energy (in this case, a cetacean call) at the various hydrophones and the distance between them, combined with the speed of sound, can be used to determine the bearing to the marine mammal. This information is graphically presented using a software interface provided by SEAMAP.

For each bearing, there is also a "mirror-image" complementary bearing on the opposite side of the ship's trackline. When only one call is detected, it is not possible to distinguish reliably, from acoustic data alone, which of the two complementary bearings is the true bearing to the mammal.

With SEAMAP and similar systems, multiple bearings are necessary to obtain an animal location. This is accomplished by repeatedly obtaining bearings to an animal as the ship moves along a straight-line. The animal's location is determined by triangulating from two or more bearings; the point at which the bearing lines intersect is the estimated location of the animal. When only one call is detected, it is not possible to determine the animal's location. Also, if the animal is moving there is some degree of error in the estimated location.

When there are successive bearings to repeated calls by the same individual cetacean or group, SEAMAP can theoretically resolve the mirror-image bearing ambiguity and provide information on the distance of the vocalizing cetacean(s) from the hydrophone array. However, in practice, it is generally not possible to localize vocalizing cetaceans based on SEAMAP alone, for a number of reasons.

The SEAMAP software manual recommends that the monitoring vessel change its heading by ~10º between successive acoustic "fixes" in order to resolve the mirror-image ambiguity and to obtain distance information on vocalizing marine mammals. This is not possible during L-DEO cruises, as it is important, for the primary purpose of the seismic survey, to maintain the planned straight-line transect. Also, the long streamer limits the *Ewing*'s turning ability.

When the calls are from a spread-out group of individuals, it is impossible to ascertain whether successive acoustic bearings are to the same animal or subgroup. With widespread groups, successive calls can originate from varying locations. The resultant sequence of bearings does not necessarily provide successive bearings to any one particular animal or subgroup.

The SEAMAP system is able to monitor broadband signals between ~8 Hz and 24 kHz. There are interference effects from ship noise and airgun sounds, although problems from ship noise appeared to be minimal. Hardware was used that filtered out sounds from airguns as they were fired (to make listening to the received signals more comfortable while using headphones). This filtering procedure filtered out all sounds for ~1–2 s so no other sounds could be heard during that interval. It is doubtful that any sequences of marine mammal vocalizations were missed as a result of the brief periods of "blanking" during the airgun shots. However, it appeared that the SEAMAP system has limited ability to detect low frequencies (<100 Hz) such as those that are typically produced by some baleen whales. When cetacean calls are detected, and the signal-to-noise ratio of the vocalizing cetaceans is judged to be adequate, the acoustic data can (when the SEAMAP system is fully functional) be saved using a quick 2-min save function or a longer 10-min recording function.

Detailed instructions on the PAM protocol followed when using SEAMAP aboard the *Ewing* are described in a user manual written specifically for *Ewing* seismic cruises (Stoltz et al. 2004).

SeaProUltra and CIBRA Monitoring System as Used during the ETPCA Cruise

The CIBRA software was also used to monitor for vocalizing cetaceans. It was initially used as a back-up system, but because of technical problems with SEAMAP, it was subsequently used as the main monitoring system. The CIBRA system functions included real-time spectrographic display, continuous and event audio recordings, navigation display, semi-automated data logging, and data logging display. These functions worked similar to those of the SEAMAP system; however, the data logging capabilities are unique to the CIBRA system and are described briefly below. A document with detailed explanations of the CIBRA system is available from CIBRA (Pavan 2005).

When a vocalization was detected, information associated with that acoustic encounter was recorded. This included the acoustic encounter identification number, whether it was linked with a visual sighting, GMT date, GMT time when first and last heard and whenever any additional information was recorded, GPS position and water depth when first detected, species or species group (e.g., unidentified dolphins, sperm whales), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The data logger, developed by CIBRA, automatically read some of this information from the *Ewing*'s navigation data stream (GPS coordinates, time, and water depth) and fed it directly into an Excel data sheet, which could then be amended and edited with the additional information.

In addition to specific event logging, the acoustic MMO on duty noted the presence or absence of cetacean signals every 15 min. The acoustic MMO also noted the seismic state, vessel activity, and any changes in the numbers of airguns operating, based on information displayed on a monitor in the acoustic work area. The acoustic MMO notified the visual MMOs on the flying bridge of these changes via telephone or radio.

When the signal-to-noise ratio of vocalizing cetaceans was judged to be adequate (moderately strong and clear vocalizations), the acoustic data were recorded onto the computer hard-drive. The CIBRA system was capable of quick 2-min recordings, or continuous recordings of a user-defined time period. On nights when acoustic MMOs were not on active duty because of a need to conduct nighttime visual observations near sea turtle beaches, the CIBRA continuous recording system was set to automatically record throughout the night, for later analysis of the acoustic recordings.

Mitigation

Ramp-up, power-down, and shut-down procedures described briefly in Chapter 3 are described in detail below. These were the primary forms of mitigation implemented during seismic operations. A ramp up consisted of a gradual increase in the number of operating airguns, not to exceed an increase of 6 dB in source level per 5 min-period. During the ETPCA project, the ramp-up rate was limited to one additional airgun per 5-min period (Appendix A). A power down consisted of reducing the number of operating airguns to one operating airgun. A shut down occurred when all the airguns were turned off.

Ramp-up Procedures

A "ramp-up" procedure was followed at the commencement of seismic operations with the 3-GI-gun array, and anytime after the array was powered down or shut down for a specified duration. Under normal operational conditions (vessel speed 4–5 kt), a ramp up was conducted after a shut down or power down lasting 4 min or longer.

The IHA required that, during the daytime, the entire safety radius be visible (i.e., not obscured by fog, etc.), and monitored for 30 min prior to and during ramp up, and that the ramp up could only commence if no marine mammals or sea turtles were detected within the safety radius during this period. Throughout the ramp ups, the safety zone was taken to be that appropriate for the entire airgun array and the water depth at the time, even though only a subset of the airguns were firing until the ramp up was completed.

Ramp up was to be suspended if marine mammals or turtles were detected within the safety radius. Ramp up of the airgun array was only permitted at night if the complete safety radius was visible (with NVDs), or when one or more airguns had been operating since sunset. It was assumed that the airgun operations would "warn" marine mammals and turtles of the approaching source vessel, allowing the animals to avoid close approaches to the source vessel; this would reduce the chance that an animal would be nearby as the airgun array was ramped up. A further condition for beginning a ramp up at night was that two trained observers using NVDs had been on watch for at least 30 min prior to the ramp up without seeing any marine mammals or sea turtles. During the cruise, NVDs could be used to monitor the safety zone for operations in intermediate and deep water (>100 m deep) but not in shallow water (<100 m). In shallow water, the safety radii were too large for the more distant portion to be monitored effectively via NVDs.

When no airguns were firing at the start of the ramp up, ramp up of the airgun array began with a single airgun. In this ETPCA project, airguns were added in a sequence such that the source level of the array would increase in steps not exceeding either one airgun or 6 dB per 5-min period. Given the small number of guns used in the full array (3), ramp-ups generally required ~10 min.

Power-down and Shut-down Procedures

Airgun operations were immediately shut down or powered down to a single operational airgun when one or more marine mammals or sea turtles were detected within, or about to enter, the appropriate safety radius (see Table 3.1 in Chapter 3).

The power-down procedure was to be accomplished within several seconds (or a "one-shot" period) of the determination that a marine mammal or sea turtle was within or about to enter the safety radius. Airgun operations were not to resume until the animal was outside the safety radius, or had not been seen for a specified amount of time (described above). Once the safety radius was judged to be clear of marine mammals or sea turtles based on those criteria, the MMOs advised the airgun operators and geophysicists, who advised the bridge that seismic surveys could re-commence, and ramp up was initiated.

In contrast to a power down, a shut down refers to the complete cessation of firing by all airguns. If a marine mammal or turtle was seen within the designated safety radius around the one airgun in operation during a power down (Table 3.1), a complete shut down was necessary.

The *Ewing* observers were located on the flying bridge or bridge about 94 m ahead of the gun array; the array was located ~39 m aft of the Ewing's stern (Fig. 2.1). The decision to initiate a power down was based on the distance from the observers rather than from the array, unless the animals were sighted close to the array. This was another precautionary measure, given that most sightings were ahead of the vessel.

Analyses

This section describes the analyses of the marine mammal and sea turtle sightings and survey effort as documented during the cruise. The analysis categories that were used were identified in Chapter 3. The primary analysis categories used to assess potential effects of seismic sounds on marine mammals were the "seismic" (airguns operating with shots at <1.5 min spacing) and "non-seismic" categories (periods >2 h after airguns were turned off). The analyses excluded the "post-seismic" period 1.5 min to 2 h after the airguns were turned off. The justification for the selection of these criteria is provided below and was previously discussed in earlier L-DEO cruise reports to NMFS (see Smultea et al. 2005; MacLean and Koski 2005).

- The period up to 1.5 min after the last seismic shot is ~10× the normal shot interval. Mammal distribution and behavior during that short period are assumed to be similar to those while seismic surveying is ongoing.
- Between 1.5 and 30 min after the cessation of seismic activities, it is likely that any marine mammals near the *Ewing* would have been "recently exposed" to sounds from the seismic survey. During at least a part of that period, the distribution and perhaps behavior of the marine mammals probably would still be influenced by the (previous) sounds.
- For some unknown part of the period from 30 min to 2 h post-seismic, it is possible that the distribution of the animals near the ship, and perhaps the behavior of some of those animals, would still be at least slightly affected by the (previous) seismic sounds.
- By 2 h after the cessation of seismic operations, the distribution and behavior of marine mammals would be expected to be indistinguishable from "normal" because of (a) waning of responses to past seismic activity, (b) re-distribution of mobile animals, and (c) movement of the ship and MMOs. Given those considerations, plus the limited observed responses of marine mammals to low-energy seismic surveys (e.g., Stone 2003; Haley and Koski 2004; MacLean and Koski 2005), it is unlikely that the distribution or behavior of marine mammals near the *Ewing* >2 h post-seismic would be appreciably different from "normal" even if they had been exposed to seismic sounds earlier. Therefore, we consider animals seen >2 h after cessation of operations by the 3-GI-gun array to be unaffected by the seismic operations.

As summarized in Chapter 3, cetacean density was one of the parameters examined to assess differences in the numbers of cetaceans between seismic and non-seismic periods. Line transect procedure for vessel-based visual surveys were followed. The formulas for calculating densities using this procedure were briefly described in Chapter 3 and are described in more detail below. As standard for line-transect estimation procedures, densities were corrected for the following two parameters before they were further analyzed:

- $g(0)$, a measure of detection bias. This factor allows for the fact that less than 100% of the animals present along the trackline are detected.
- $f(0)$, the reduced probability of detecting an animal with increasing distance from the track-line.

The $g(0)$ and $f(0)$ factors used in this study were taken from results of previous work, not from observations made during this study. Sighting rates during the present study were either too small or, at most, marginal to provide meaningful data on $f(0)$ based on group size. Further, this type of project cannot provide data on $g(0)$. Estimates of these correction factors were taken from Koski et al. (1998) and Ferguson and Barlow (2001) for corresponding species and Beaufort Wind Forces. Marine mammal sightings were subjected to species-specific truncation criteria as used in the above-cited analyses of marine mammal sightings. It should be recognized that the use of $f(0)$ and $g(0)$ factors from other studies conducted in other locations is a first approximation, with no allowance for differences in observation procedures, ship speeds, etc. However, the use of these "best available" correction factors is preferable to the alternative of ignoring the need for such factors.

Number of Exposures.—Estimates of the numbers of potential *exposures* of marine mammals to sound levels ≥160 dB re 1 µPa (rms) were calculated by multiplying the following three values. These calculations were done separately for times when different numbers of airguns were in use, and the results were summed:

- number of kilometers of seismic survey,
- width of the area assumed to be ensonified to ≥160 dB (2 × 160 dB radius, depending on the airgun array in use at the time; Table D.2), stratified based on three different water depth ranges (Table 3.1), and
- "corrected" densities of marine mammals estimated by line transect methods as summarized above.

Number of Individuals Exposed.—The estimated number of individual exposures to levels ≥160 dB obtained by the method described above likely overestimates the number of different *individual* mammals exposed to the GI-gun sounds at received levels ≥160 dB. This occurs because some exposure incidents may have involved the same individuals previously exposed, given that some seismic lines crossed other lines (see Fig. 1.1).

A minimum estimate of the number of different individual marine mammals potentially exposed (one or more times) to ≥160 dB re 1 μPa (rms) was calculated. That involved multiplying the corrected density of marine mammals by the area exposed to ≥160 dB one or more times during the course of the study. The area was calculated using MapInfo Geographic Information System (GIS) software by creating a "buffer" that extended on both sides of the vessel's trackline to the predicted 160-dB radius. Because the 160-dB radius varied with water depth and the source (Table 4.8), the width of the buffer also varied with water depth and the source (Table D.2). The buffer includes areas that were exposed to airgun sounds ≥160 dB multiple times (as a result of crossing tracklines or tracklines that were close enough for their 160 dB zones to overlap). The buffer area only counts the repeated-coverage areas once, as opposed to the "exposures" method outlined above. The calculated number of different individual marine mammals exposed to ≥160 dB re 1 μPa (rms) is considered a minimum estimate because it does not account for the movement of marine mammals during the course of the study. In actuality, the estimated numbers of individuals and of exposures were generally similar (see Chapter 4). This was a result of the small assumed disturbance radius in water depths >100 m during this ETPCA study, the small amount of overlap of the survey lines in those water depths, and the low proportion of the study conducted in water <100 m deep where the overlap was greater.

The buffer process outlined above was repeated for delphinids, assuming that for those animals, the estimated 170 dB radius (see Table 4.8) was a more realistic estimate of the maximum distance at which significant disturbance would occur. That radius was used to estimate both the number of exposures and the number of individuals exposed to seismic sounds with received levels ≥170 dB re 1 μPa (rms). The process was also repeated for all cetacean species based on the estimated 180-db radius. That was done to estimate the numbers of animals that would have been subjected to sounds with received levels ≥180 dB re 1 μPa (rms) if they had not altered their course to avoid those sound levels (or the ship).

TABLE D.2. The areas (km^2) potentially ensonified to various levels by the GI guns during seismic periods, stratified by water depth, during the ETPCA seismic cruise, 21 Nov.–22 Dec. 2004. ***(A)*** Maximum area ensonified, with overlapping areas counted multiple times. ***(B)*** Total area ensonified at least once, with overlapping areas counted only once.

A. Including Overlap Area

	Water Depth (m)			
Sound Criterion	<100	100–1000	>1000	Total
160 dB	4168	6274	1302	11,743
170 dB	2052	1968	406	4426
180 dB	866	602	124	1592
190 dB	573	187	40	800

B. Excluding Overlap Area

	Water Depth (m)			
Sound Criterion	<100	100–1000	>1000	Total
160 Db	3671	5501	1235	10,407
170 dB	1961	1880	396	4237
180 dB	851	591	122	1564
190 dB	566	186	39	791

APPENDIX E:
BACKGROUND ON MARINE MAMMALS IN ETPCA PROJECT REGION

APPENDIX E.1. The habitat, abundance, and conservation status of marine mammals inhabiting the ETPCA seismic survey area in the Eastern Tropical Pacific Ocean.

Species	Habitat	Abundance in the ETP[1]	U.S. ESA[2]	IUCN[3]	CITES[4]
Odontocetes					
Sperm whale (*Physeter macrocephalus*)	Usually pelagic, deep sea	26,053[◊]	Endangered	VU[†]	I
Pygmy sperm whale (*Kogia breviceps*)	Deep waters off the shelf	N.A.	Not listed	N.A.	II
Dwarf sperm whale (*Kogia sima*)	Deep waters off the shelf	11,200[#]	Not listed	N.A.	II
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	20,000	Not listed	DD	II
Longman's beaked whale (*Indopacetus pacificus*)	Pelagic	N.A.	N.A.	DD	II
Pygmy beaked whale (*Mesoplodon peruvianus*)	Deep waters	25,300[^]	Not listed	DD	II
Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*)	Likely pelagic	25,300[^]	Not listed	DD	II
Blainville's beaked whale (*Mesoplodon densirostris*)	Pelagic	25,300[^]	Not listed	DD	II
Rough-toothed dolphin (*Steno bredanensis*)	Mostly pelagic	145,900	Not listed	DD	II
Bottlenose dolphin (*Tursiops truncatus*)	Coastal and oceanic	243,500	Not listed	DD	II
Pantropical spotted dolphin (*Stenella attenuata*)	Coastal and pelagic	2,059,100	Not listed	LR-cd	II
Spinner dolphin (*Stenella longirostris*)	Coastal and pelagic	1,651,100	Not listed	LR-cd	II
Striped dolphin (*Stenella coeruleoalba*)	Off the continental shelf	1,918,000	Not listed	LR-cd	II
Short-beaked common dolphin (*Delphinus delphis*)	Continental shelf and pelagic waters	3,093,300	Not listed	N.A.	II*
Fraser's dolphin (*Lagenodelphis hosei*)	Water >1000 m	289,300	N.A.	DD	II
Risso's dolphin (*Grampus griseus*)	Waters >1000 m	175,800	Not listed	DD	II
Melon-headed whale (*Peponocephala electra*)	Oceanic	45,400	Not listed	N.A.	II
Pygmy killer whale (*Feresa attenuata*)	Deep, pantropical waters	38,900	Not listed	DD	II
False killer whale (*Pseudorca crassidens*)	Pelagic	39,800	Not listed	N.A.	II
Killer whale (*Orcinus orca*)	Widely distributed	8500	Not listed	LR-cd	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Mostly pelagic	160,200[º]	Not listed	LR-cd	II
Mysticetes					
Humpback whale (*Megaptera novaeangliae*)	Mainly near-shore waters and banks	1177[@]	Endangered	VU	I
Minke whale (*Balaenoptera acutorostrata*)	Continental shelf, coastal waters	N.A.	Not listed	LR-cd	I
Bryde's whale (*Balaenoptera edeni*)	Pelagic and coastal	13,000[Δ]	Not listed	DD	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	N.A.	Endangered	EN	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	1851[@]	Endangered	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	1400	Endangered	EN	I

N.A. - Data not available or species status was not assessed.

[1] Abundance estimates for the ETP from Wade and Gerrodette (1993).
[2] Endangered Species Act (Carretta et al. 2002, 2003).
[3] Codes for IUCN classifications: EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened); DD = Data Deficient. Classifications are from the 2003 IUCN *Red List of Threatened*

Species, although the status of marine mammals has not been reassessed since 1996.
[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2003).
[#] This abundance estimate is mostly for *K. sima* but may also include some *K. breviceps.*
[^] This estimate includes all species of the genus *Mesoplodon.*
[o] This estimate is mostly for *G. macrorhynchus* but may include some *G. melas.*
[@] From Barlow and Taylor (2001) for populations off the California, Oregon, Washington, and Baja coasts.
[Δ] This estimate is mostly for *Balaenoptera edeni* but may include some *B. borealis*.
[◊] From Whitehead (2002).
* No distinction is made between *D. delphis* and *D. capensis.*

APPENDIX E.2. Densities of cetaceans off the west coast of Central America based on past surveys in the region of the Nov. – Dec. 2004 ETPCA seismic survey area. Densities are from Ferguson and Barlow (2001) and the appendix to that report. Densities are corrected for *f*(0) and *g*(0) biases. The 2004 ETPCA survey was conducted in block 118 of Ferguson and Barlow (2001). Adjacent blocks are 119, 138 and 139. Species listed as endangered are in italics.

Species	Observed Density in Block 118 (# / km^2)[a]		Average Density in Block 118 and Adjacent Coastal Blocks (# / km^2)[a]		Maximum Density in Block 118 and Adjacent Coastal Blocks (# / km^2)[a]	
	Density	CV[b]	Density	CV	Density	CV
Odontocetes						
Sperm whale	*0.0003*	>1.00	*0.0029*	*0.40*	*0.0048*	*0.55*
Pygmy sperm whale	0.0000	-1.00	0.0000	-1.00	0.0000	-1.00
Dwarf sperm whale	0.0274	0.52	0.0235	0.36	0.0293	0.46
Cuvier's beaked whale	0.0073	0.51	0.0068	0.37	0.0078	0.51
Tropical bottlenose whale	0.0000	-1.00	0.0000	-1.00	0.0000	-1.00
Pygmy beaked whale	0.0000	-1.00	0.0000	-1.00	0.0000	-1.00
Blainville's beaked whale	0.0000	-1.00	0.0000	-1.00	0.0000	-1.00
Mesoplodon sp. (unidentified)	0.0015	0.76	0.0014	0.57	0.0016	0.76
Rough-toothed dolphin	0.0035	0.94	0.0105	0.46	0.0157	0.54
Tucuxi	0.0000	-1.00	0.0000	-1.00	0.0000	-1.00
Bottlenose dolphin	0.0529	0.49	0.0589	0.16	0.1038	0.28
Spotted dolphin	0.1387	0.23	0.1950	0.22	0.3394	0.31
Spinner dolphin	0.0029	>1.00	0.1420	0.32	0.3619	0.36
Costa Rican spinner dolphin	0.1487	0.94	0.0163	0.94	0.1547	0.94
Clymene dolphin	0.0000	-1.00	0.0000	-1.00	0.0000	-1.00
Striped dolphin	0.2650	0.51	0.2013	0.15	0.3389	0.51
Short-beaked common dolphin	0.1976	0.58	0.1640	0.28	0.2690	0.38
Fraser's dolphin	0.0000	-1.00	0.0000	-1.00	0.0000	-1.00
Risso's dolphin	0.0098	0.76	0.0128	0.38	0.0227	0.54
Melon-headed whale	0.0000	-1.00	0.0022	0.94	0.0110	0.94
Pygmy killer whale	0.0001	>1.00	0.0043	0.76	0.0103	0.94
False killer whale	0.0000	-1.00	0.0000	-1.00	0.0000	-1.00
Killer whale	0.0000	-1.00	0.0002	0.72	0.0002	0.94
Short-finned pilot whale	0.0100	0.72	0.0179	0.30	0.0311	0.37
Mysticetes						
Humpback whale	*0.0000*	*-1.00*	*0.0000*	*-1.00*	*0.0000*	-1.00
Minke whale	0.0000	-1.00	0.0000	-1.00	0.0000	-1.00
Bryde's whale	0.0000	-1.00	0.0003	0.94	0.0007	0.94
Sei whale	*0.0000*	*-1.00*	*0.0000*	*-1.00*	*0.0000*	-1.00
Fin whale	*0.0000*	*-1.00*	*0.0000*	*-1.00*	*0.0000*	-1.00
Blue whale	*0.0000*	*-1.00*	*0.0003*	*0.60*	*0.0006*	0.65

[a] Densities for each species include allowance for sightings not identified to species.

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

APPENDIX F:
ADDITIONAL VISUAL AND PASSIVE ACOUSTIC MONITORING (PAM) RESULTS

APPENDIX F.1. Useable[a] marine mammal observation effort from the *Ewing* during the ETPCA seismic cruise, 21 Nov. – 22 Dec. 2004, in ***(A)*** hours and ***(B)*** kilometers, subdivided by water depth and GI gun activity[b]. Ramp-up [c] effort is included in the "GI Guns On" category.

	Water Depth Range (m)			
GI gun Status	**<100**	**100-1000**	**>1000**	**Total**
***(A)* Observation Effort (h)**				
GI Guns On				
1–90 s after shutdown	1	2	0	2
Ramp Up [c]	2	2		4
1 GI gun	1	4	1	7
2 GI guns	**8**	12	15	36
3 GI guns	29	151	27	206
GI Guns Off				
In seismic survey area	1	2		4
In transit from Costa Rica	2	6	1	8
In transit to Panama		7	14	21
Total	**44**	**186**	**58**	**288**
***(B)* Observation Effort (km)**				
GI Guns On				
1–90 s after shutdown	5	14	1	20
Ramp Up [c]	19	13		31
1 GI gun	9	36	11	56
2 GI guns	**72**	**101**	119	**292**
3 GI guns	241	**1269**	215	**1725**
GI Guns Off				
In seismic survey area	12	18		30
In transit from Costa Rica	30	142	13	186
In transit to Panama		119	276	395
Total	**388**	**1713**	**634**	**2734**

[a] See *Acronyms and Abbreviations* for the definition of "useable" effort.

[b] Slight differences in column and row totals due to rounding errors.

[c] Ramp up involved gradually increasing the number of operating GI guns from 0 or 1 GI gun at a rate of no greater than 1 GI gun per 5-min period or approximately 6 dB per 5- min period until all 3 GI guns were operating.

APPENDIX F.2. All (and useable[a]) visual observation effort from the *Ewing* during the ETPCA seismic cruise, 21 Nov. – 22 Dec. 2004, in ***(A)*** hours, and ***(B)*** kilometers, subdivided by Beaufort Wind Force (Bf) and airgun status. Ramp-up effort is included in the "GI Guns On" category. SA refers to effort within the seismic survey area only where the seismic lines were located.

GI Gun Status	0	1	2	3	4	5	6	7	Total
(A) Effort in h									
Total GI Guns On	1	39 (*14*)	62 (*34*)	89 (*62*)	109 (*72*)	125 (*74*)	72	10	507 (*256*)
Total GI Guns Off	0	8 (*5*)	14 (*7*)	13 (*7*)	12 (*9*)	3 (*1*)	1	0	51 (*29*)
Pre-seismic SA				1					1
90 s-2 h Post-seismic SA		3	7	5	3	2	1	0	21
Non-seismic SA (>2 h post-seismic)									0
Non-seismic transit from Costa Rica		3 (3)	5 (5)						8 (8)
Non-seismic transit to Panama		2 (2)	2 (2)	7 (7)	9 (9)	1 (1)			21 (21)
Total	**1**	**47 (*19*)**	**76 (*41*)**	**102 (*69*)**	**121 (*81*)**	**128 (*75*)**	**73**	**10**	**558 (*285*)**
(B) Effort in km									
Total GI Guns On	8	324 (*114*)	519 (*281*)	758 (*533*)	912 (*593*)	1001 (*604*)	561	80	4163 (*2125*)
Total GI Guns Off	0	127 (*104*)	249 (*167*)	182 (*131*)	191 (*161*)	49 (*17*)	3	0	800 (*580*)
Pre-seismic SA 90 s - 2 h				8					8
Post-seismic SA		23	59	43	26	15	3	0	169
Non-seismic SA (>2 h post-seismic)			23			9			32
Non-seismic transit from Costa Rica		59 (*59*)	126 (*126*)						185 (*185*)
Non-seismic transit to Panama		45 (*45*)	41 (*41*)	131 (*131*)	165 (*161*)	25 (*17*)			407 (*395*)
Total	**8**	**451 (*218*)**	**768 (*448*)**	**940 (*664*)**	**1103 (*754*)**	**1050 (*621*)**	**564**	**80**	**4963 (*2705*)**

[a] See *Acronyms and Abbreviations* for the definition of "useable".

[b] Ramp up involved gradually increasing the number of operating GI guns from 0 or 1 GI gun at a rate of no greater than 1 GI gun per 5-min period or approximately 6 dB per 5-min period until all 3 GI airguns were operating.

APPENDIX F.3. Visual Sightings and Acoustic Detections of Cetaceans Made from the R/V *Maurice Ewing* during the ETPCA Seismic Survey (including Transits) in the Eastern Tropical Pacific Ocean off Central America, 21 Nov.–22 Dec. 2004. No pinnipeds were seen during the survey.

SPECIES	Visual (V) or Acoustic (A) detection?[a]	Useable (Y) or Non-Useable (N)[b]	Grp Size	Day in 2004	Time (GMT)	Latitude (°N)	Longitude (°W)	Sighting Distance (m) (Distance from FB/B[c] to sighting)	CPA[d] (m) (Distance from cetacean group to GI gun(s))	Initial Move-ment[e]	Initial Behavior[f]	Bf[g]	Water depth[h] (m)	Vessel Activ.[i]	# GI Guns On	Array Vol.	Max. Estim. Received Sound Level (dB) at Sighting Location	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)[j]
Unident. dolphin	V	Y	3	21-Nov	17:25:54	9.55466	-84.8918	200	229	SP	SW	1	100-1000	OT	0	0	None	L	
Unident. dolphin	V	Y	1	21-Nov	18:38:03	9.4493	-85.0907	1000	1046	ST	SW	2	100-1000	OT	0	0	None	L	
Bottlenose dolphin	V	Y	12	21-Nov	20:23:25	9.56958	-85.4006	700	92	ST	SW	2	100-1000	OT	0	0	None	L	
Bottlenose dolphin	V	Y	10	21-Nov	21:19:27	9.67269	-85.5699	928	377	MI	SW	2	100-1000	OT	0	0	None	L	
Unident. dolphin	V	Y	5	21-Nov	21:23:06	9.6795	-85.5811	736	676	SP	SW	2	100-1000	OT	0	0	None	L	
Bottlenose dolphin	V	Y	6	21-Nov	21:26:50	9.68656	-85.5925	928	676	SP	SW	2	100-1000	OT	0	0	None	L	
Bottlenose dolphin	V	Y	3	21-Nov	21:31:26	9.69512	-85.6066	928	91	ST	SW	2	100-1000	OT	0	0	None	L	
Unident. dolphin	V	Y	3	21-Nov	21:48:21	9.72692	-85.6589	3151	3075	SP	SW	2	100-1000	OT	0	0	None	L	
Unident. dolphin	V	Y	8	21-Nov	22:17:10	9.78284	-85.7504	533	527	SP	SW	2	100-1000	OT	0	0	None	L	
Unident. dolphin	V	Y	1	21-Nov	23:06:00	9.89748	-85.8972	150	173	SP	SW	2	100-1000	OT	0	0	None	L	
Unident. dolphin	A	Y		22-Nov	0:48:00	10.1213	-86.122					3	>1000	OT	0	0		D	
Unident. dolphin	A	Y		22-Nov	2:00:00	10.1819	-86.1104						100-1000	SH	1			D	
Unident. dolphin	A	Y		22-Nov	3:36:00	10.2808	-86.0352						100-1000	SH	1			D	
Unident. dolphin	A	Y		22-Nov	7:47:00	10.525	-85.9812						<100	LS	3			D	
Unident. dolphin	A	Y		22-Nov	11:24:00	10.3963	-85.9857					3	<100	LS	3	135		D	
Unident. dolphin	A	Y		22-Nov	12:29:00	10.332	-86.0185					3	<100	SH	2	90		L	
Unident. dolphin	A	Y		22-Nov	14:15:00	10.4082	-86.126					4	100-1000	LS	3	135		L	
Unident. dolphin	A	Y		22-Nov	17:24:28	10.3071	-86.0936					3	159	LS	3	135		L	
Spinner dolphin	V	Y	600	22-Nov	19:11:08	10.2939	-86.1447	2729	2045	SA	SW	3	506	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	A	Y		22-Nov	22:48:00	10.2677	-86.1838					3	952	LS	3	135		L	
Unident. dolphin	A	Y		22-Nov	23:40:00	10.2263	-86.145					2	814	SH	2	90		L	
Unident. dolphin	A	Y		23-Nov	1:28:00	10.1792	-86.2259						1665.4	LS	3			D	
Unident. dolphin	A	Y		23-Nov	3:56:00	10.2295	-86.3466						2081.9	SH	2			D	
Unident. dolphin	A	Y		23-Nov	5:55:00	10.192	-86.3212						2194.9	LS	3			D	
Unident. dolphin	A	Y		23-Nov	8:01:00	10.3045	-86.2078						795	LS	3			D	
Unident. dolphin	A	Y		23-Nov	9:26:00	10.3808	-86.1307						137	LS	3			D	
Unident. dolphin	A	Y		23-Nov	10:46:00	10.4505	-86.0602						106.8	LS	3			D	
Unident. dolphin	A	Y		23-Nov	11:52:00	10.5093	-86.001					3	95.4	LS	3	135		L	
Unident. dolphin	A	Y		23-Nov	13:14:00	10.5829	-85.9264					4	92	LS	3	135		L	
Pantropical spotted dolphin	V	Y	1	23-Nov	14:39:11	10.6426	-85.8355	30	67	SP	SW	2	76	SZ	0	0	190 dB (2 GI guns)	L	PDSZ
Unident. dolphin	A	Y		23-Nov	16:17:00	10.5505	-85.8778					2	80	SZ	0	135		L	
Unident. dolphin	A	Y		23-Nov	19:35:00	10.5343	-85.8944					2	80.6	OT	0	0		L	
Unident. dolphin	V	Y	2	23-Nov	20:56:32	10.4624	-85.9674	20	91	MI	SW	2	86	OT	0	0	None	L	
Pantropical spotted dolphin	V	Y	2	23-Nov	21:39:04	10.4252	-86.0054	1427	1287	SP	SW	2	95	OT	0	0	None	L	
Unident. dolphin	A	Y		24-Nov	0:30:00	10.2741	-86.159						706.4	LS	3			D	
Unident. dolphin	A	Y		24-Nov	1:55:00	10.1994	-86.2349					2	1428.9	LS	3	135		D	
Unident. dolphin	A	Y		24-Nov	3:18:00	10.1299	-86.3113					3	2451	LS	3	135		D	
Unident. dolphin	A	Y		24-Nov	4:34:00	10.1978	-86.2898					3	1998	LS	3	135		D	
Unident. dolphin	A	Y		24-Nov	5:41:00	10.2571	-86.2291					3	1100.2	LS	3	135		D	
Unident. dolphin	A	Y		24-Nov	6:50:00	10.3187	-86.1663					3	478.2	LS	3	135		D	
Unident. dolphin	A	Y		24-Nov	9:30:00	10.4612	-86.0216					3	99.5	LS	3	135		D	
Unident. dolphin	A	Y		24-Nov	10:30:00	10.5146	-85.9673					4	88.9	LS	3	135		D	
Unident. dolphin	A	Y		24-Nov	11:48:00	10.5872	-85.9251					3	91.4	SH	2	90		L	
Unident. dolphin	A	Y		24-Nov	14:20:00	10.4683	-86.0674					2	107.5	RU	1	45		L	
Unident. dolphin	A	Y		24-Nov	15:45:00	10.394	-86.143					2	182	LS	3	135		L	
Unident. dolphin	V	Y	2	24-Nov	15:50:58	10.3887	-86.1484	343	407	SA	SW	2	204	LS	3	135	160 dB (3 GI guns)	L	
Spinner dolphin	V	Y	400	24-Nov	17:02:00	10.3259	-86.2122	4633	867	SA	FE	2	856.2	SH	1	45	<160 dB (1 GI gun)	L	
Unident. dolphin	V	Y	1	24-Nov	17:40:30	10.2921	-86.2466	1017	1063	SP	SW	2	1307	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	A	Y		24-Nov	20:17:00	10.2077	-86.3854					1	2490.2	SH	2	90		L	

SPECIES	Visual (V) or Acoustic (A) detection?[a]	Useable (Y) or Non-Useable (N)[b]	Grp Size	Day in 2004	Time (GMT)	Latitude (°N)	Longitude (°W)	Sighting Distance (m) (Distance from FB/B[c] to sighting)	CPA[d] (m) (Distance from cetacean group to GI gun(s))	Initial Move-ment[e]	Initial Behavior[f]	Bf[g]	Water depth[h] (m)	Vessel Activ.[i]	# GI Guns On	Array Vol.	Max. Estim. Received Sound Level (dB) at Sighting Location	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)[j]
Unident. dolphin	V	Y	4	24-Nov	21:22:00	10.2352	-86.3149	847	218	ST	SW	1	1888	SH	2	90	160 dB (2 GI guns)	L	
Unident. dolphin	A	Y		24-Nov	21:22:00	10.2352	-86.3149					1	1891.5	SH	2	90		L	
Unident. dolphin	A	Y		24-Nov	22:15:00	10.1864	-86.3273					1	2270.6	LS	3	135		L	
Unident. dolphin	V	N	6	24-Nov	22:51:07	10.1546	-86.3602	4633	2454	SP	PO	1	2698	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	V	Y	3	24-Nov	23:00:09	10.147	-86.368	2410	2485	MI	BR	1	2849	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	A	Y		24-Nov	23:47:00	10.1064	-86.4094					1	3470	LS	3	135		D	
Unident. dolphin	A	Y		25-Nov	0:25:00	10.0733	-86.4434					1	4007	LS	3	135		D	
Unident. dolphin	A	Y		25-Nov	3:18:00	9.92083	-86.5191					3	4236	SH	2	90		D	
Unident. dolphin	A	Y		25-Nov	4:20:00	9.97402	-86.463					2	4834	LS	3	135		D	
Unident. dolphin	A	Y		25-Nov	6:15:00	10.0774	-86.3587					2	3041.8	LS	3	135		D	
Unident. dolphin	A	Y		25-Nov	7:13:44	10.1293	-86.3064					2	2460	LS	3	135		D	
Unident. dolphin	A	Y		25-Nov	10:20:00	10.1816	-86.2795					2	1934.8	LS	3	135		D	
Bottlenose dolphin	V	Y	15	25-Nov	11:40:30	10.2527	-86.207	200	87	SP	BR	2	1090	LS	3	135	170 dB (3 GI guns)	L	PD
Unident. dolphin	A	Y		25-Nov	13:18:32	10.3398	-86.1185					2	141.7	LS	3	135		L	
Unident. dolphin	A	Y		25-Nov	14:32:56	10.4053	-86.052					2	103	LS	3	135		L	
Unident. dolphin	V	Y	3	25-Nov	14:51:16	10.4214	-86.0354	650	676	SP	PO	2	102	LS	2	90	<160 dB (2 GI guns	L	
Unident. dolphin	A	Y		25-Nov	15:10:26	10.4387	-86.018					2	102	LS	2	90		L	
Humpback whale	V	Y	2	25-Nov	16:35:50	10.5144	-85.9412	654	278	SA	TR	2	86	LS	3	135	190 dB (3 GI guns)	L	PD
Unident. dolphin	A	Y		25-Nov	18:35:04	10.5654	-85.8273					4	73	RU	88	99		L	
Unident. dolphin	A	Y		26-Nov	9:27:06	11.3795	-86.6157					4	130	LS	3	135		D	
Unident. dolphin	A	Y		26-Nov	14:24:40	11.6657	-86.8939					3	111	LS	3	135		L	
Unident. dolphin	A	Y		26-Nov	17:04:48	11.82	-87.0438					3	111	LS	3	135		L	
Unident. dolphin	V	Y	3	26-Nov	17:10:30	11.8255	-87.0491	1337	477	SA	PO	3	112	LS	3	135	160 dB (3 GI guns)	L	
Pantropical spotted dolphin	V	Y	1	26-Nov	20:02:02	11.9829	-87.202	854	587	ST	BR	3	116	LS	3	135	160 dB (3 GI guns)	L	
Unident. dolphin	A	Y		27-Nov	0:51:04	12.1253	-87.0773						74	LS	3			D	
Unident. dolphin	A	Y		27-Nov	4:08:10	11.937	-86.895						79	LS	3			D	
Unident. dolphin	A	Y		27-Nov	5:58:18	11.8335	-86.7947						76	LS	3			D	
Unident. dolphin	A	Y		27-Nov	12:57:10	11.8934	-86.9168					4	87	LS	3	135		L	
Unident. dolphin	V	N	3	27-Nov	17:25:42	12.1255	-87.1621	1017	1063	SP	FE	2	93	OT	0	0	None but ExposedWithin90s	L	
Unident. dolphin	A	Y		27-Nov	17:26:26	12.1249	-87.1628					2	89	OT	0	0		L	
Unident. dolphin	A	Y		27-Nov	23:27:18	11.7796	-86.8814					2	98	SH	2	90		L	
Unident. dolphin	A	Y		28-Nov	0:01:22	11.7592	-86.9144						105	SH	2			D	
Unident. dolphin	A	Y		28-Nov	0:41:28	11.7952	-86.9509						107	LS	3			D	
Unident. dolphin	A	Y		28-Nov	1:48:30	11.8583	-87.0118					1	109	LS	3	135		D	
Unident. dolphin	A	Y		28-Nov	2:22:04	11.8907	-87.0433					1	108	LS	3	135		D	
Unident. dolphin	A	Y		28-Nov	2:52:54	11.9198	-87.0714					1	107	LS	3	135		D	
Unident. dolphin	V	N	3	28-Nov	2:57:05	11.9238	-87.0753	30	91	SP	BR	1	109	PD	1	45	170 dB (1 GI gun)	D	PD
Unident. dolphin	A	Y		28-Nov	8:06:24	11.9254	-87.2058					1	117	LS	3	135		D	
Unident. dolphin	A	Y		28-Nov	9:03:30	11.872	-87.1541					1	116	LS	3	135		D	
Unident. dolphin	A	Y		28-Nov	9:44:19	11.8341	-87.1174					0	113.1	LS	3	135		D	
Unident. dolphin	A	Y		28-Nov	11:14:26	11.7519	-87.0378					1	116	LS	3	135		D	
Unident. dolphin	A	Y		28-Nov	11:19:54	11.7469	-87.033					1	116	LS	3	135		D	
Unident. dolphin	A	Y		28-Nov	11:24:54	11.7424	-87.0286					1	116	LS	3	135		D	
Unident. dolphin	A	Y		28-Nov	11:37:44	11.7308	-87.0176					2	116	LS	3	135		L	
Unident. dolphin	A	Y		28-Nov	11:46:52	11.7227	-87.0096					2	115	LS	3	135		L	
Unident. dolphin	V	Y	1	28-Nov	13:01:36	11.6485	-87.0111	3151	3238	SA	BR	3	123	SH	2	90	<160 dB (2 GI guns	L	
Unident. dolphin	A	Y		28-Nov	13:24:06	11.6298	-87.0335					3	129	SH	2	90		L	
Unident. dolphin	V	Y	6	28-Nov	13:44:44	11.6393	-87.0581	654	576	SP	FL	4	131	LS	3	135	160 dB (3 GI guns)	L	
Unident. dolphin	A	Y		28-Nov	14:15:04	11.6698	-87.0871					4	131	LS	3	135		L	
Unident. dolphin	A	Y		28-Nov	15:33:46	11.7465	-87.1614					4	126	LS	3	135		L	
Unident. dolphin	A	Y		29-Nov	1:14:54	11.5958	-87.1445						113	LS	3			D	

SPECIES	Visual (V) or Acoustic (A) detection?[a]	Useable (Y) or Non-Useable (N)[b]	Grp Size	Day in 2004	Time (GMT)	Latitude (°N)	Longitude (°W)	Sighting Distance (m) (Distance from FB/B[c] to sighting)	CPA[d] (m) (Distance from cetacean group to GI gun(s))	Initial Move-ment[e]	Initial Behavior[f]	Bf[g]	Water depth[h] (m)	Vessel Activ.[i]	# GI Guns On	Array Vol.	Max. Estim. Received Sound Level (dB) at Sighting Location	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)[j]
Unident. dolphin	A	Y		29-Nov	2:25:56	11.5278	-87.1318						122	SH	2			D	
Unident. dolphin	A	Y		29-Nov	3:54:58	11.5422	-87.2213						215	LS	3			D	
Unident. dolphin	A	Y		29-Nov	8:32:32	11.8005	-87.4959						239	SH	2			D	
Unident. dolphin	A	Y		29-Nov	9:50:16	11.7306	-87.4688						409	LS	3			D	
Unident. dolphin	A	Y		29-Nov	10:17:34	11.7098	-87.4485						437	LS	3			D	
Unident. dolphin	A	Y		29-Nov	11:44:08	11.6443	-87.3852					5	478	LS	3	135		L	
Unident. dolphin	V	Y	20	29-Nov	11:51:59	11.6382	-87.3791	1650	1502	SA	PO	5	480	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	V	Y	1	29-Nov	12:15:42	11.6198	-87.3614	389	466	UN	UN	5	486	LS	3	135	160 dB (3 GI guns)	L	
Unident. dolphin	A	Y		29-Nov	13:10:14	11.5785	-87.3214					5	449	LS	3	135		L	
Unident. dolphin	A	Y		29-Nov	16:23:30	11.4374	-87.1988					6	487	SH	2	90		L	
Unident. dolphin	A	Y		29-Nov	19:08:36	11.552	-87.3586					4	709	LS	3	135		L	
Unident. dolphin	V	Y	20	29-Nov	19:23:36	11.5668	-87.3731	1125	1170	SP	BR	4	741	LS	3	135	<160 dB (3 GI guns	L	
Humpback whale	V	Y	1	29-Nov	19:37:12	11.5805	-87.386	1427	730	SA	DI	4	766	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	A	Y		29-Nov	20:01:58	11.6047	-87.4097					4	801	LS	3	135		L	
Spinner dolphin	V	Y	350	29-Nov	21:37:06	11.6981	-87.5001	4633	3044	SP	BR	3	744	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	V	Y	2	29-Nov	22:36:40	11.735	-87.5637	450	499	SP	SW	3	925	SH	2	90	160 dB (2 GI guns)	L	
Unident. dolphin	A	Y		30-Nov	1:26:30	11.6062	-87.4761						1107	LS	3			D	
Unident. dolphin	A	Y		30-Nov	6:13:14	11.4397	-87.315						802	LS	3			D	
Unident. dolphin	A	Y		30-Nov	6:52:04	11.4188	-87.2947						814	LS	3			D	
Unident. dolphin	A	Y		30-Nov	7:07:00	11.4107	-87.2868						818	LS	3			D	
Unident. dolphin	A	Y		30-Nov	7:34:12	11.396	-87.2727						840	LS	3			D	
Unident. dolphin	A	Y		30-Nov	7:43:20	11.3911	-87.2678						864	LS	3			D	
Unident. dolphin	A	Y		30-Nov	7:59:38	11.3791	-87.2623						910	SH	2			D	
Unident. dolphin	A	Y		30-Nov	10:57:22	11.4921	-87.4291						1112	LS	3			D	
Unident. dolphin	A	Y		30-Nov	13:18:50	11.6436	-87.5756					5	1385	LS	3	135		L	
Unident. dolphin	A	Y		30-Nov	17:23:12	11.6533	-87.5727					5	1341	LS	3	135		L	
Unident. dolphin	A	Y		30-Nov	18:32:56	11.7118	-87.515					4	764	LS	3	135		L	
Unident. dolphin	A	Y		30-Nov	20:25:08	11.817	-87.412					3	182	LS	3	135		L	
Unident. dolphin	A	Y		30-Nov	23:10:08	11.9697	-87.2623					2	124	LS	3	135		L	
Unident. dolphin	A	Y		1-Dec	1:28:14	12.0962	-87.1382					3	94	LS	3	135		D	
Unident. dolphin	A	Y		1-Dec	4:00:01	12.1374	-87.0365					3	66	LS	3	135		D	
Unident. dolphin	A	Y		1-Dec	7:17:17	11.9589	-87.2211					3	115	LS	3	135		D	
Unident. dolphin	A	Y		1-Dec	9:15:46	11.8531	-87.3249						130.5	LS	3			D	
Unident. dolphin	A	Y		1-Dec	14:12:16	11.7797	-87.4384					5	231.9	OT	0	0		L	
Unident. dolphin	A	Y		1-Dec	18:45:10	11.5523	-87.6078					4	1759.8	SH	2	90		L	
Unident. dolphin	A	Y		2-Dec	2:06:20	11.8829	-87.2437						120.3	LS	3			D	
Unident. dolphin	A	Y		2-Dec	2:36:40	11.9096	-87.2174						119.3	LS	3			D	
Unident. dolphin	A	Y		2-Dec	3:43:46	11.9696	-87.1585					4	114.4	LS	3	135		D	
Unident. dolphin	A	Y		2-Dec	7:09:38	12.1274	-86.973					4	50.7	SH	2	90		D	
Unident. dolphin	A	Y		2-Dec	8:39:59	12.0408	-87.0369					5	84	LS	3	135		D	
Unident. dolphin	A	Y		2-Dec	14:50:56	11.6902	-87.381					5	336.4	LS	3	135		L	
Unident. dolphin	A	Y		2-Dec	15:35:02	11.6482	-87.4221					5	706.2	LS	3	135		L	
Unident. dolphin	A	Y		2-Dec	16:32:08	11.5929	-87.4765					5	1150	LS	3	135		L	
Unident. dolphin	A	Y		2-Dec	19:19:38	11.4782	-87.6513					3	2646.2	SH	2	210		L	
Unident. dolphin	A	Y		2-Dec	19:58:44	11.5142	-87.6274					3	1968	SH	1	105		L	
False killer whale	V	Y	12	2-Dec	21:15:02	11.5716	-87.5657	2410	231	ST	PO	3	1579	SH	3	315	<160 dB (3 GI guns	L	
Unident. dolphin	A	Y		2-Dec	22:00:20	11.5592	-87.5369					3	1520	SH	2	210		L	
Unident. dolphin	A	Y		3-Dec	1:54:28	11.3523	-87.7378						4859.7	LS	3			D	
Unident. dolphin	A	Y		3-Dec	3:51:16	11.26	-87.828						5052.3	LS	3			D	
Unident. dolphin	A	Y		4-Dec	0:39:16	12.0774	-86.948						59.9	LS	3			D	
Unident. dolphin	A	Y		4-Dec	2:13:00	12.1624	-86.8645						30.6	LS	3			D	

SPECIES	Visual (V) or Acoustic (A) detection?[a]	Useable (Y) or Non-Useable (N)[b]	Grp Size	Day in 2004	Time (GMT)	Latitude (°N)	Longitude (°W)	Sighting Distance (m) (Distance from FB/B[c] to sighting)	CPA[d] (m) (Distance from cetacean group to GI gun(s))	Initial Move-ment[e]	Initial Behavior[f]	Bf[g]	Water depth[h] (m)	Vessel Activ.[i]	# GI Guns On	Array Vol.	Max. Estim. Received Sound Level (dB) at Sighting Location	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)[j]
Unident. dolphin	A	Y		4-Dec	4:56:30	12.1251	-86.9793						52.4	LS	3			D	
Unident. dolphin	A	Y		5-Dec	1:38:14	11.8485	-87.122						114.9	LS	3			D	
Unident. dolphin	A	Y		5-Dec	2:30:46	11.8895	-87.0814						113.5	LS	3			D	
Unident. dolphin	A	Y		5-Dec	4:26:50	11.989	-86.9839						85.5	LS	3			D	
Unident. dolphin	A	Y		5-Dec	4:49:46	12.0098	-86.9635						80.6	LS	3			D	
Unident. dolphin	A	Y		5-Dec	7:10:26	11.9823	-86.9384						80.8	LS	3			D	
Unident. dolphin	A	Y		5-Dec	9:14:50	11.863	-87.0553						110.4	LS	3			D	
Short-finned pilot whale	V	Y	5	5-Dec	18:41:47	11.4071	-87.4507	389	439	SP	PO	5	1468	SH	2	90	<160 dB (2 GI guns	L	
Unident. dolphin	A	Y		5-Dec	23:04:14	11.593	-87.2684					4	244	LS	3	135		L	
Unident. dolphin	A	Y		6-Dec	2:10:28	11.7241	-87.1399						125.6	LS	3			D	
Unident. dolphin	A	Y		6-Dec	3:41:00	11.791	-87.0745						116.4	LS	3			D	
Unident. dolphin	A	Y		6-Dec	4:04:26	11.8106	-87.0553						115.5	LS	3			D	
Unident. dolphin	A	Y		6-Dec	14:21:34	11.6443	-87.1668					3	123.5	LS	3	135		L	
Unident. dolphin	A	Y		6-Dec	19:41:12	11.327	-87.4808					3	2860.6	SH	2	90		L	
Unident. dolphin	A	Y		7-Dec	3:07:50	11.5598	-87.1972						150.3	LS	3			D	
Unident. dolphin	A	Y		7-Dec	5:05:16	11.6584	-87.1006						126.2	LS	3			D	
Unident. dolphin	A	Y		7-Dec	8:16:14	11.8312	-86.931						101.1	LS	3			D	
Unident. dolphin	A	Y		7-Dec	10:08:28	11.9315	-86.8325						69.1	LS	3			D	
Unident. dolphin	V	Y	8	7-Dec	12:50:42	11.8413	-86.8689	993	1039	SA	PO	3	88	LS	3	135	160 dB (3 GI guns)	L	
Unident. dolphin	A	Y		7-Dec	12:51:32	11.8406	-86.8696					3	89.2	LS	3	135		L	
Unident. dolphin	A	Y		7-Dec	13:25:16	11.8104	-86.8998					3	99.4	LS	3	135		L	
Unident. whale	V	Y	1	7-Dec	13:36:56	11.8	-86.91	450	527	SP	BL	2	b100-1000	LS	3	135	160 dB (3 GI guns)	L	
Unident. whale	V	Y	1	7-Dec	13:50:45	11.7879	-86.9218	1650	1695	SA	SW	2	105	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	V	Y	6	7-Dec	13:51:44	11.787	-86.9227	1258	1303	MI	FE	2	106	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	A	Y		7-Dec	18:45:02	11.53	-87.1748					4	140.9	LS	3	135		L	
Unident. dolphin	A	Y		8-Dec	2:46:10	11.5405	-87.2424						286	LS	3			D	
Unident. dolphin	A	Y		8-Dec	16:58:10	12.1518	-87.7475					4	140.4	LS	3	135		L	
Unident. dolphin	A	Y		8-Dec	17:17:30	12.1664	-87.7618					4	136.3	OT	0	0		L	
Unident. dolphin	A	Y		9-Dec	1:25:24	12.5465	-88.1335						91.9	LS	3			D	
Unident. dolphin	A	Y		9-Dec	2:39:42	12.6055	-88.1913						94.6	LS	3			D	
Unident. dolphin	A	Y		9-Dec	5:56:38	12.6882	-88.3278					1	101.9	SH	2	90		D	
Humpback whale	V	Y	2	9-Dec	16:14:45	13.1244	-87.7131	3151	89	ST	SW	2	29	LS	3	135	190 dB (3 GI guns)	L	PDSZ
Humpback whale	V	Y	1	9-Dec	17:15:18	13.1619	-87.647	60	123	SP	BL	1	28	SZ	0	0	190 dB (2 GI guns)	L	SZ
Humpback whale	V	Y	1	9-Dec	18:15:23	13.1169	-87.668	654	701	UN	BL	1	24.4	LS	3	135	170 dB (3 GI guns)	L	
Humpback whale	V	Y	2	9-Dec	19:28:33	13.0499	-87.7347	2000	647	UN	BL	1	35	LS	3	135	<160 dB (3 GI guns	L	
Humpback whale	V	Y	1	9-Dec	19:55:54	13.0255	-87.7594	4813	2301	SA	BL	1	38	LS	3	135	<160 dB (3 GI guns	L	
Humpback whale	V	Y	2	9-Dec	20:39:37	12.9859	-87.7993	1519	996	SP	BL	1	35	LS	3	135	170 dB (3 GI guns)	L	
Humpback whale	V	Y	2	9-Dec	21:25:28	12.9446	-87.8412	4633	4708	SA	BL	3	45	LS	3	135	<160 dB (3 GI guns	L	
Humpback whale	V	Y	1	9-Dec	21:36:54	12.9347	-87.8513	3306	3350	ST	BL	3	46	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	A	Y		10-Dec	2:38:34	12.6787	-88.1104					3	75.3	LS	3	135		D	
Unident. dolphin	A	Y		10-Dec	8:57:06	12.4338	-87.8951					1	87.1	LS	3	135		D	
Unident. dolphin	A	Y		10-Dec	13:22:02	12.1837	-87.6513					5	119.6	LS	3	135		L	
Unident. dolphin	A	Y		10-Dec	13:45:58	12.1599	-87.6277					5	122.7	LS	3	135		L	
Humpback whale	V	Y	1	10-Dec	17:25:33	11.9593	-87.4327	450	458	SP	TR	4	133	LS	3	135	160 dB (3 GI guns)	L	
Unident. dolphin	A	Y		10-Dec	19:29:56	11.8494	-87.3257					2	130.7	LS	3	135		L	
Unident. dolphin	V	Y	1	10-Dec	20:44:00	11.788	-87.2661	200	218	ST	SW	1	130	LS	3	135	170 dB (3 GI guns)	L	
Unident. dolphin	A	Y		10-Dec	20:45:10	11.787	-87.2652					1	131	LS	3	135		L	
Unident. dolphin	A	Y		11-Dec	19:26:22	10.8334	-86.556					6	231.8	LS	3	135		L	
Unident. dolphin	A	Y		12-Dec	0:43:32	10.7123	-86.7218					6	1588.2	LS	3	135		D	
Unident. dolphin	A	Y		12-Dec	1:07:40	10.7343	-86.7009					6	1232.4	LS	3	135		D	
Unident. dolphin	A	Y		12-Dec	1:44:06	10.7671	-86.6698					6	886	LS	3	135		D	

SPECIES	Visual (V) or Acoustic (A) detection?[a]	Useable (Y) or Non-Useable (N)[b]	Grp Size	Day in 2004	Time (GMT)	Latitude (°N)	Longitude (°W)	Sighting Distance (m) (Distance from FB/B[c] to sighting)	CPA[d] (m) (Distance from cetacean group to GI gun(s))	Initial Move-ment[e]	Initial Behavior[f]	Bf[g]	Water depth[h] (m)	Vessel Activ.[i]	# GI Guns On	Array Vol.	Max. Estim. Received Sound Level (dB) at Sighting Location	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)[j]
Unident. dolphin	A	Y		12-Dec	2:08:14	10.7897	-86.6485					6	696.9	LS	3	135		D	
Unident. dolphin	A	Y		12-Dec	11:40:42	11.3151	-86.1518					4	76.9	LS	3	135		L	
Unident. dolphin	A	Y		12-Dec	17:33:04	11.1967	-86.3625					5	131.1	LS	3	135		L	
Unident. dolphin	A	Y		13-Dec	0:03:24	10.8462	-86.6962					5	699.3	LS	3	135		D	
Unident. dolphin	A	Y		13-Dec	1:14:08	10.7861	-86.7533					5	1390.8	LS	3	135		D	
Unident. dolphin	A	Y		13-Dec	1:41:06	10.7622	-86.7759					5	1663.3	LS	3	135		D	
Unident. dolphin	A	Y		13-Dec	3:26:46	10.6958	-86.7874					5	2295.5	SH	2	90		D	
Unident. dolphin	A	Y		13-Dec	5:23:14	10.8056	-86.6842					5	782	LS	3	135		D	
Unident. dolphin	A	Y		13-Dec	5:57:58	10.8371	-86.6545					5	617.6	LS	3	135		D	
Unident. dolphin	A	Y		13-Dec	9:58:20	11.0598	-86.4435					6	180.2	LS	3	135		D	
Unident. dolphin	A	Y		13-Dec	10:40:10	11.0979	-86.4074					6	165.8	LS	3	135		D	
Unident. dolphin	A	Y		13-Dec	10:54:16	11.1107	-86.3952					6	161.3	LS	3	135		D	
Pantropical spotted dolphin	V	N	3	13-Dec	12:34:28	11.2033	-86.3073	90	177	SP	BR	6	118	LS	3	135	170 dB (3 GI guns)	L	
Unident. dolphin	A	Y		13-Dec	15:37:32	11.331	-86.2889					5	83.4	LS	3	135		L	
Unident. dolphin	A	Y		14-Dec	0:38:50	10.8421	-86.7518					5	1168	LS	3	135		D	
Unident. dolphin	A	Y		14-Dec	10:06:24	10.8809	-86.7659					6	1171	LS	3	135		D	
Unident. dolphin	A	Y		14-Dec	10:38:46	10.9099	-86.7385					6	978	LS	3	135		D	
Unident. dolphin	A	Y		15-Dec	0:13:00	11.2765	-86.4169					5	117.4	LS	3	135		D	
Unident. dolphin	A	Y		15-Dec	0:32:18	11.2579	-86.4346					5	129.8	LS	3	135		D	
Unident. dolphin	A	Y		16-Dec	5:00:06	10.9059	-86.4142					5	192.3	SH	2	90		D	
Unident. dolphin	A	Y		16-Dec	6:20:34	10.9697	-86.3537					5	184.1	SH	2	90		D	
Unident. dolphin	A	Y		16-Dec	8:41:58	11.1075	-86.4792					7	178.6	LS	3	135		D	
Unident. dolphin	A	Y		16-Dec	9:17:04	11.141	-86.5121					7	178.1	LS	3	135		D	
Unident. dolphin	A	Y		16-Dec	17:29:58	11.614	-86.971					4	121.2	LS	3	135		L	
Unident. dolphin	A	Y		17-Dec	1:19:34	11.8744	-87.3302					3	126.4	LS	3	135		D	
Unident. dolphin	A	Y		17-Dec	2:05:30	11.8311	-87.3726					3	152.6	LS	3	135		D	
Pantropical spotted dolphin	V	N	4	17-Dec	3:41:13	11.738	-87.4637	20	91	SP	SW	4	367	PD	1	45	170 dB (1 GI gun)	D	PD
Unident. dolphin	A	Y		17-Dec	6:53:00	11.5503	-87.6147					3	1756.6	SH	2	90		D	
Unident. dolphin	A	Y		17-Dec	8:11:46	11.6112	-87.5359					4	1331.4	LS	3	135		D	
Unident. dolphin	V	N	2	17-Dec	8:22:27	11.6217	-87.5257	5	89	SP	SW	4	1234	LS	3	135	170 dB (3 GI guns)	D	
Unident. dolphin	V	N	8	17-Dec	9:27:48	11.6818	-87.4668	5	89	SP	SW	4	705	LS	3	135	180 dB (3 GI guns)	D	
Unident. dolphin	A	Y		17-Dec	14:09:02	11.9502	-87.2035					5	115.4	OT	0	0		L	
Bottlenose dolphin	V	Y	4	17-Dec	15:04:16	12.0045	-87.1501	315	92	ST	SW	4	107	LS	3	135	170 dB (3 GI guns)	L	
Unident. dolphin	A	Y		17-Dec	17:18:18	12.1351	-87.022					2	57.9	LS	3	135		L	
Unident. dolphin	A	Y		17-Dec	22:03:54	11.8986	-87.1505					2	114.1	LS	3	135		L	
Unident. dolphin	A	Y		18-Dec	1:23:24	11.7091	-87.3365					2	207	LS	3	135		D	
Pantropical spotted dolphin	V	Y	4	18-Dec	2:49:34	11.6248	-87.4191	5	87	ST	BO	2	764	LS	3	135	180 dB (3 GI guns)	D	PD
Unident. dolphin	A	Y		18-Dec	6:31:38	11.5249	-87.465					1	1254.3	LS	3	135		D	
Pantropical spotted dolphin	V	N	8	18-Dec	8:50:34	11.6615	-87.3312	10	91	SP	SW	3	262	PD	1	45	170 dB (1 GI gun)	D	PD
Unident. dolphin	A	Y		18-Dec	10:03:02	11.7358	-87.2908					3	156.4	SH	2	90		D	
Pantropical spotted dolphin	V	Y	50	18-Dec	12:24:08	11.6047	-87.2139	1650	1334	SP	PO	3	155	LS	3	135	<160 dB (3 GI guns	L	
Unident. dolphin	A	Y		18-Dec	13:36:46	11.5334	-87.145					3	125.9	LS	3	135		L	
Pantropical spotted dolphin	V	Y	100	18-Dec	16:27:23	11.3667	-86.9838	1017	694	SP	PO	4	163	LS	3	135	160 dB (3 GI guns)	L	
Unident. dolphin	V	Y	1	18-Dec	17:23:34	11.3121	-86.9308	533	540		BR	4	158	LS	3	135	160 dB (3 GI guns)	L	
Unident. dolphin	A	Y		18-Dec	18:33:42	11.2432	-86.8642					4	190.4	LS	3	135		L	
Unident. dolphin	A	Y		18-Dec	18:45:04	11.2318	-86.8532					4	195.9	LS	3	135		L	
Unident. whale	V	Y	1	18-Dec	19:03:35	11.2135	-86.8355	847	893	SA	BL	4	204	LS	3	135	160 dB (3 GI guns)	L	
Unident. dolphin	A	Y		19-Dec	2:21:14	10.9688	-86.5992					5	160.4	LS	3	135		D	
Unident. dolphin	A	Y		19-Dec	4:01:32	10.8721	-86.5058					5	188.8	LS	3	135		D	
Unident. dolphin	A	Y		19-Dec	10:12:10	10.5176	-86.1638						140.8	LS	3			D	
Pantropical spotted dolphin	V	Y	35	19-Dec	16:49:54	10.2604	-86.1517	350	92	ST	PO	5	805	LS	3	135	170 dB (3 GI guns)	L	

SPECIES	Visual (V) or Acoustic (A) detection?[a]	Useable (Y) or Non-Useable (N)[b]	Grp Size	Day in 2004	Time (GMT)	Latitude (ºN)	Longitude (ºW)	Sighting Distance (m) (Distance from FB/B[c] to sighting)	CPA[d] (m) (Distance from cetacean group to GI gun(s))	Initial Move-ment[e]	Initial Behavior[f]	Bf[g]	Water depth[h] (m)	Vessel Activ.[i]	# GI Guns On	Array Vol.	Max. Estim. Received Sound Level (dB) at Sighting Location	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)[j]
Unident. dolphin	A	Y		20-Dec	0:31:02	9.98644	-85.9815						990.3	LS	3			D	
Unident. dolphin	A	Y		20-Dec	1:42:24	9.93015	-85.9335						962.7	LS	3			D	
Unident. dolphin	A	Y		20-Dec	1:57:12	9.91912	-85.9243						1003.2	LS	3			D	
Pantropical spotted dolphin	V	Y	10	20-Dec	12:05:36	9.36403	-85.1966	2160	1246	MI	LT	4	1210	OT	0	0	None	L	
Unident. dolphin	V	Y	20	20-Dec	12:31:11	9.3292	-85.1321	1258	876	PE	PO	4	1822	OT	0	0	None	L	
Unident. dolphin	V	N	10	20-Dec	13:48:48	9.19975	-84.9434	1256	804	SP	PO	4	1901	OT	0	0	None	L	
Pantropical spotted dolphin	V	N	15	20-Dec	14:01:46	9.17332	-84.9151	650	95	MI	BR	5	1970	OT	0	0	None	L	
Short-beaked common dolphi	V	Y	45	20-Dec	14:24:30	9.12916	-84.8632	450	278	MI	FE	4	1321	OT	0	0	None	L	
Unident. dolphin	V	Y	1	20-Dec	15:45:28	8.99467	-84.6658	800	846	NO	BR	2	1398	OT	0	0	None	L	
Unident. dolphin	V	N	20	20-Dec	15:59:53	8.97325	-84.6293	4633	4677	UN	PO	2	1070	OT	0	0	None	L	
Risso's dolphin	V	Y	25	20-Dec	17:22:20	8.83569	-84.4273	1017	264	MI	SW	1	1853	OT	0	0	None	L	
Unident. dolphin	V	Y	100	20-Dec	17:36:10	8.81204	-84.3942	2410	2044	MI	FE	1	1753	OT	0	0	None	L	
Long-beaked common dolphir	V	Y	15	20-Dec	18:06:57	8.75863	-84.3196	232	278	SA	SW	1	1394	OT	0	0	None	L	
Short-finned pilot whale	V	Y	15	20-Dec	18:15:56	8.74324	-84.2975	1650	1695	SP	SW	1	1284	OT	0	0	None	L	
Short-finned pilot whale	V	Y	3	20-Dec	18:23:12	8.731	-84.2794	600	449	SP	SW	1	1157	OT	0	0	None	L	
Bottlenose dolphin	V	Y	15	20-Dec	18:23:13	8.73097	-84.2794	400	351	MI	SW	1	1157	OT	0	0	None	L	
Short-finned pilot whale	V	Y	7	20-Dec	18:24:43	8.72846	-84.2757	500	287	SA	SW	1	1180	OT	0	0	None	L	
Bottlenose dolphin	V	Y	4	20-Dec	18:24:44	8.72843	-84.2756	300	87	PE	BO	1	1180	OT	0	0	None	L	
Pantropical spotted dolphin	V	Y	10	20-Dec	20:58:10	8.48148	-83.9113	2410	1472	SA	BR	3	721	OT	0	0	None	L	
Minke whale	V	N	1	21-Dec	17:22:34	6.98972	-80.9828	350	312	SP	SW	3	1889	OT	0	0	None	L	
Unident. toothed whale	V	Y	4	21-Dec	19:20:21	7.00511	-80.64	115	92	ST	SW	3	1819	OT	0	0	None	L	

[a] Visual/acoustic detections. Thirty lines are duplicated because they represent 2 detections, 1 visual, 1 acoustic, of the same group/individual.

[b] Usable or Nonusable sightings. Y=Visual sightings made during daylight periods both within the seismic survey area and during transit to and from that area, N=periods 90 s to 2 h after guns were turned off (post-seismic), night-time observations, poor visibility conditions (visibility <3.5 km), and periods with Beaufort Wind Force >5 (>2 for cryptic species). Also excluded were periods when the *Ewing*'s speed was <3.7 km/h (2 kt) or with >1 radian of severe glare between 90º left and 90º right of the bow.

[c] Sighting distance. FB/B=flying bridge/bridge

[d] CPA is the distance at the closest observed point of approach to the nearest airgun. This is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel.

[e] The initial movement of the individual or group relative to the vessel. MI=milling, NO=no movement, PE=swimming perpendicular to ship or across bow, SA=swimming away, SP=swimming parallel, ST=swimming toward, UN=unknown.

[f] The initial behavior observed. BL=blowing, BO=bow riding, BR=breaching, DE=dead, DI=diving, FE=feeding, FL=fluking, LG=logging, LT=lobtail, MI=milling, OT=other, PO=porpoising, RE=resting, SW=swimming, TR=traveling, UN=unknown.

[g] Beaufort Wind Force scale (which is not the same as the "Sea State" scale).

[h] Water depth was recorded for the vessel's location when a sighting was made.

[i] Activity of the vessel at the time of the sighting. SH=operating airguns offline usually during turns between seismic lines, LS=operating airguns on a seismic survey line and collecting geophysical data, PD=power down of airguns, RU=ramp up, SZ=shut down for mammal in safety zone, OT=other (a period of no seismic activity either during transit or a period after an SZ).

[j] Mitigating measures. SZ= safety zone shut down, PD=power down, None.

APPENDIX F.4. Total number of groups (individuals in parentheses) of cetacean species observed from the *Ewing* during the ETPCA seismic cruise, 21 Nov.–22 Dec. 2004. SA refers to sightings made within and between the grids where the seismic lines were located, and transits refer to travel to and from ports outside the survey grids (see Fig. 1.1). See Table 4.1 for the total number of useable[a] sightings (a subtotal of the numbers shown here) used in cetacean behavior and density analyses Species listed under the U.S. ESA as Endangered are in italics.

	Within and Between Seismic Grids [b]				Transit (Non-seismic) [c]			
Species	**Pre-seismic**	**Seismic**	**90 s- 2 h Post-Seismic**	**Non-seismic (>2 h after GI guns stopped)**	**Transit from Costa Rica**	**Transit to Panama**	**Total Group Sightings**	**Total Individuals**
Delphinids								
Bottlenose dolphin		2 (19)			4 (31)	2 (19)	8	69
Spotted dolphin		9 (201)		1 (2)		3 (35)	13	238
Spinner dolphin		3 (1350)					3	1350
Short-beaked common dolphin						1 (45)	1	45
Unidentified common dolphin						1 (15)	1	15
Risso's dolphin						1 (25)	1	25
False killer whale		1 (12)					1	12
Short-finned pilot whale		1 (5)				3 (25)	4	30
Unidentified dolphin		20 (101)	1 (3)	1 (2)	6 (21)	5 (151)	33	278
Mysticetes								
Humpback whale		*11 (16)*					*11*	*16*
Minke whale						1(1)	1	1
Unidentified Whale [d]		3 (3)				1 (4)	4	7
Total Cetaceans		**50 (1707)**	**1 (3)**	**2 (4)**	**10 (52)**	**18 (320)**	**81**	**2086**

[a] See *Acronyms and Abbreviations* for the definition of "useable".

[b] See Figure 1.1 for locations of grids where seismic survey lines were located.

[c] Transits to and from ports; excludes the area identified in footnote b above.

[d] Unidentified whales include unidentified toothed whales and unidentified whales.

APPENDIX F.5. Pantropical spotted dolphin that followed the *Ewing* over a ~26-h period on 23–24 Nov. 2004.

As noted in Chapter 4, a lone pantropical spotted dolphin was sighted repeatedly near the *Ewing* for over 26 h on 23 and 24 Nov. 2004. This dolphin was seen in the Gulf of Papagayo off the Nicoya Peninsula, off northwestern Costa Rica, between 10°17' and 10°39' N, and 85°50'–86°11' W; water depths during sightings ranged from ~75 to 390 m (Fig. 4.2). The dolphin was recognized by unique physical characteristics seen and noted by the MMOs. A chronological description of this encounter is provided in the table below.

In general, the dolphin's behavior was variable. It was seen and heard vocalizing during both seismic and non-seismic periods, and approached and lingered close (~20–80 m) to the GI guns and *Ewing* on numerous occasions. The dolphin swam around the *Ewing* and GI-gun array on multiple occasions. It followed the *Ewing* for ~9 h on one occasion while the GI guns were off. A ramp up was then conducted after the dolphin moved out of the safety radius for one GI gun; the ramp up to 3 GI guns was completed after the dolphin moved out of the associated safety radius (see Table, below). One power down and two shut downs of the GI guns were conducted for this pantropical spotted dolphin. One of the shut downs was triggered by an initial acoustic detection, followed by a visual sighting.

The first time the individual was encountered it was detected only acoustically, when 3 GI guns had previously been operating continuously for ~37 h. It was first detected visually ~5 min later, ~20 m from the operating GI guns over water depths of ~76 m at the stern of the *Ewing*. The animal was within the safety radius at this time, so a shut down was implemented. The dolphin stopped and started vocalizing on numerous occasions, including during a ramp up, while the GI guns were off, and while 3 GI guns were operating. It was also sighted and heard calling while 2 and 1 GI guns were on.

There were seven acoustic detections of this same pantropical spotted dolphin over the course of the ~26-h encounter period, as confirmed by visual sightings of the same individual as described above. Out of the seven times the animal was detected, it was initially detected acoustically six out of those seven times; only on one occasion was the dolphin seen first and then heard vocalizing. On average, vocalizations from this individual lasted for ~47 min (ranging from 20 to 88 min), and a total of 5.5 h of vocalizations were documented. The animal was detected acoustically during periods with and without GI gun operations..

In summary, observations may indicate that this lone pantropical spotted dolphin became habituated to the small GI gun array. The estimated received sound levels of the GI guns near this dolphin are described in Appendix G.

continued/…

APPENDIX F.5 (concluded). Pantropical spotted dolphin that followed the *Ewing* over a ~26-h period on 23–24 Nov. 2004.

Date	Time (GMT)	Seismic Activity	Number of GI Guns On	Behavior	Comments
23/11/04	14:14	LS	3	Vocalizing	1 to 3 GI guns had been firing for 36.75 h when dolphin was first acoustically detected
23/11/04	14:19	SH	2	Vocalizing	Powered down during turn
23/11/04	14:39	SZ	0	Vocalizing, seen ~20 m from the firing GI guns	***Shut down*** for dolphin
23/11/04	14:55	RU	88	Vocalizing	Ramping up
23/11/04	14:59	RU	88	Stopped vocalizing	Ramping up
23/11/04	17:26	OT	0	Started vocalizing	The GI guns had been shut down for 30 min
23/11/04	17:29	RU	88	Vocalizing	Ramping up
23/11/04	18:01	SH	2	Vocalizing	Ramping up
23/11/04	18:16	SZ	0	Stopped vocalizing	Shut down for turtle
23/11/04	18:25	OT	0	Seen swimming around the ship ~50 m away, across bow, then back to stern	Still shut down for turtles and dolphin
23/11/04	18:52	OT	0	Started vocalizing again, still seen swimming around vessel	GI guns had been shut down for ~35 min
23/11/04	19:27	OT	0	Stopped vocalizing but still seen swimming near stern of vessel	Still shut down for turtles and dolphin
23/11/04	19:42	OT	0	Still seen swimming around vessel	Still shut down for turtles and dolphin
23/11/04	20:37	OT	0	Started vocalizing	GI guns had been shut down for 2.35 h
23/11/04	20:40	OT	0	Seen swimming around the ship ~30 m away	Still shut down for turtles and dolphin
23/11/04	21:25	OT	0	Still seen swimming around vessel ~25 m away	Still shut down for turtles and dolphin
23/11/04	21:27	OT	0	Stopped vocalizing	Still shut down for turtles and dolphin
23/11/04	21:45	OT	0	Started vocalizing	GI guns had been shut down for 3.5 h
23/11/04	22:05	OT	0	Stopped vocalizing	Still shut down for turtles and dolphin
23/11/04	22:07	OT	0	Seen swimming ~60 m from ship	Still shut down for turtles and dolphin
23/11/04	22:15	OT	0	Started vocalizing	Still shut down for turtles and dolphin, GI guns had been shut down for 4 h
23/11/04	23:00	SH	1	Vocalizing	Dolphin had been following ship for ~8.75 h, so it was decided to start ramp up when dolphin moved outside of the safety radius for 1 GI gun. Ramp up to the second gun was not initiated until the dolphin moved out of the entire safety radius for the 3-GI-gun array.
23/11/04	23:45	SH	2	Vocalizing	Dolphin was not seen anymore, but could still be heard vocalizing
23/11/04	23:52	LS	3	Vocalizing	Line shooting
24/11/04	00:08	LS	3	Stopped vocalizing	Line shooting
24/11/04	12:25	LS	3	Started vocalizing	Had been shooting GI guns for 13.4 h
24/11/04	12:28	SZ	0	Vocalizing, dolphin seen ~80 m from array	***Shut down*** for dolphin
24/11/04	13:21	OT	0	Stopped vocalizing	Last time dolphin was heard vocalizing
24/11/04	16:21	PD	1	Seen swimming ~50 m from ship	***Power down*** for dolphin, GI guns had been firing for 2.4 h, last time dolphin was seen

APPENDIX F.6. Marine mammal passive acoustic monitoring effort (PAM) from the *Ewing* during the ETPCA seismic cruise, 21 Nov. – 22 Dec. 2004, in ***(A)*** hours and ***(B)*** kilometers, subdivided by night versus day and GI gun activity.

Seismic Status	**Night**	**Day**	**Total**
(A) **Acoustic Effort (h)**			
GI guns on			
1 GI gun	5	7	12
2 GI guns	34	40	74
3 GI guns	269	248	517
Variable (e.g., ramp up)	0	4	4
0 GI guns (up to 90 s after shot)	0	2	0
GI Guns off	1	22	23
Total	**309**	**324**	**632**
(B) **Acoustic Effort (km)**			
GI guns on			
1 GI gun	42	57	99
2 GI guns	271	324	595
3 GI guns	2204	2056	4259
Variable (e.g., ramp up)	3	31	35
0 GI guns (up to 90 s after shot)	1	20	21
GI Guns off	8	184	192
Total	**2529**	**2672**	**5200**

APPENDIX G:
SIGHTINGS WITH POWER DOWNS AND SHUT DOWNS, ETPCA CRUISE, 21 NOV. – 22 DEC. 2004

Six of the 12 cetacean sightings that resulted in power downs or shut downs of the GI guns were in shallow (<100 m) water where the 180 dB safety radius was 433 m, and the remaining six occurred in intermediate depth (100–1000 m) water, where the safety radius was 93 m (Table 3.1). Of the nine different cetacean groups (mitigation measures had to be implemented three times for one individual pantropical spotted dolphin and twice for the same humpback), some or all members of three groups were definitely exposed to levels ≥180 dB, as follows:

- A single pantropical spotted dolphin was first seen on 23 Nov. at 14:39 GMT in 76 m of water. It was initially seen swimming ~30 m from the portside GI gun. At that time, only 2 GI guns were firing. It was initially sighted by the airgun operators at the stern of the vessel. The airgun operators immediately shut down the GI guns when they discovered the dolphin, although they believed that it had already been there for a short period of time. The safety radius for this GI gun configuration was 433 m, and the 180 dB radius for 2 GI guns (90 in^3) was 400 m. Thus, the dolphin was ***definitely*** exposed to sound levels ≥180 dB on this occasion. The same individual was seen several times over the next eight hours or so swimming alongside the vessel, while the GI guns were shut down. The dolphin remained within the safety radius for the 3-GI-gun array during that period. Once the vessel reached intermediate waters (108 m), and the animal was outside of the 180 dB distance for one 45 in^3 GI gun (41 m), it was decided to start operating the single GI gun. The animal remained outside the one GI gun distance but within the safety radius of the 3-GI-gun array for 1.5 h, and then it was not sighted again.
- The same individual pantropical spotted dolphin was seen again on 24 Nov. at 18:27:56 GMT in 96 m of water. Three GI guns were in operation at the time, and the dolphin was seen swimming ~80 m alongside the ship. Since the safety radius was 433 m, the GI guns were shut down. The dolphin continued to follow alongside of the ship, after the GI guns had been shut down, for the next 1.5 h. After that time, the ship entered intermediate water (103 m), and the dolphin swam beyond the safety radius. The GI guns were then ramped up. Therefore, on this occasion, the dolphin was ***definitely*** exposed to sound levels ≥180 dB again.
- The pantropical spotted dolphin appeared again at 16:21:20 GMT on the same day (24 Nov.), when 3 GI guns were operating in intermediate (389 m) water. It was swimming alongside the ship at ~50 m, so the GI guns were powered down to one GI gun. The safety radius for the 3-GI-gun array was 93 m, and for the single GI gun it was 41 m. Therefore, on this occasion, the animal was ***unlikely*** to have been exposed to sound levels ≥180 dB, especially since it was spending much of its time at the water surface. On that occasion, the dolphin was seen for <30 min.
- Two groups totaling 15 bottlenose dolphins were first seen swimming parallel to the *Ewing* in deep water when 3 GI guns were in operation. They were seen breaching and porpoising 200 m ahead of the vessel and appeared to be feeding in the area. They then swam parallel to the vessel in the opposite direction to the ship's heading and were near the vessel for ~15 min. They subsequently came to bowride when the vessel was in intermediate-depth water (985 m). The 180 dB safety radius was 93 m, and the animals at the bow were situated ~110 m

from the GI guns. A power down was implemented as a precautionary measure, and the GI guns were ramped up after the dolphins left, after ~4 min. Given that the bowriding animals spent much of the time at the water surface, it is ***unlikely*** that any of these animals were exposed to ≥180 dB.

- A group of two humpback whales (a mother-calf pair) was seen in shallow (85 m) water during the operation of 3 GI guns. The whales were first sighted because of a blow ~654 m ahead of the vessel. The animals then swam along the starboard side of the vessel and blows were seen again ~654 m away. Five minutes later, the whales were seen 450 m ahead of the vessel. The safety radius was 433 m, and the GI guns were powered down as a precautionary measure. The whales then approached the vessel and were seen ~200 m away from the one firing GI gun. As the shut-down radius for one GI gun was 189 m, the GI gun was not shut down. The animals were seen again 7 min later ~654 m away, and were not seen again after that. Because the animals were at the surface when they were first sighted, and beyond the 180-dB (rms) sound radius, it is ***unlikely*** that they were exposed to received levels ≥180 dB (rms).
- A group of three unidentified dolphins was sighted in intermediate-depth (109 m) water during operations with 3 GI guns at night. They were initially seen with night-vision devices swimming parallel to the vessel ~130 m away from the GI guns, as well as breaching occasionally. The dolphins then approached the vessel to bowride. The safety radius for intermediate-depth water was 93 m, so the GI guns were powered down as a precautionary measure. Because the animals were bowriding and beyond the 180 dB (rms) radius, it is ***unlikely*** that they were exposed to received levels ≥180 dB (rms).
- On 9 Dec., a group of two humpback whales was first seen in shallow (29 m) water in the Gulf of Fonseca, ~3151 m ahead of the vessel. The vessel was operating 3 GI guns at the time. Only one animal was seen initially. It dove twice, was seen once 1650 m away, and then again 450 m away ~10 min later. As a precautionary measure, the GI guns were powered down, because the 180-dB safety radius for shallow water was 433 m. Another humpback appeared ~3 min afterwards ~90 m from the operating GI gun, and the GI gun was shut down immediately. The first whale seen was sighted outside of the 180-dB radius and was thus ***unlikely*** to have been exposed to GI gun pulses ≥180 dB (rms). However, the second whale was seen only 90 m away from the one operating GI gun and within the 180-dB safety radius. Although the whale was seen at the surface of the water, it was ***definitely*** exposed to at least one or two shots from the firing GI gun before the shut down was implemented.
- On the same day ~1 h later, one humpback whale was seen in shallow (28 m) water ~123 m away from the two firing GI guns, as the vessel was turning onto a new line. The GI guns were shut down immediately, as the 180-dB safety radius at the time was 433 m. Because the vessel was turning away from the whale, the animal was outside of the safety radius ~5 min afterwards, and the GI guns were ramped up again. Because the whale was seen inside the safety radius, it ***definitely*** was exposed to several GI gun sound pulses with received sound levels ≥180 dB.
- On 17 Dec., a group of four pantropical spotted dolphins was seen in intermediate-depth water (367 m) when 3 GI guns were firing. The dolphins were seen swimming in the same direction as the vessel ~90 m away from the operating GI guns. They were first seen with

NVDs after whistles were heard via PAM. A power down was implemented immediately. The dolphins then came to bowride and were located ~110 m from the operating GI gun, and outside of the safety radius. Nonetheless, ramp up to the full 3-GI-gun array did not occur until ~1 h after the animals were initially sighted. After the ramp up was complete, the dolphins were still seen bowriding. About 20 min after ramp up was complete, two dolphins were still seen bowriding. These last two dolphins were spotted swimming away from the vessel ~2 h after they were initially seen. Because the animals were seen bowriding and thus at the surface of the water, it is ***unlikely*** that they were exposed to sound levels ≥180 dB.

- The following night (18 Dec.), another group of four pantropical spotted dolphins was sighted swimming towards the vessel to bowride in intermediate-depth (~800 m) water. Three GI guns were firing, a power down was implemented, and the dolphins remained at the bow. They swam away ~35 min after they were first seen, and the guns were powered up again. It is ***unlikely*** that these dolphins were exposed to sound levels ≥180 dB because, at the bow, they were outside the safety radius. Also, the fact that the animals were bowriding means that they spent much time at the surface of the water, which further reduced the chance that they were exposed to sound pulses ≥180 dB.
- The same night, ~6 h later, a group of three pantropical spotted dolphins was seen bowriding. They were then joined by five more dolphins. The water depth was ~262 m, and a power down was implemented as a precautionary measure. PAM showed that the whistles associated with these dolphins were becoming fainter, and a ramp up was initiated after ~18 min, when the dolphins were still bowriding. When the ramp up was initiated, the dolphins quickly swam away from the bow and were not seen again. Because the animals were outside the 180-dB safety radius and they were mainly at the water surface while bowriding, it is ***unlikely*** that they were exposed to sound levels ≥180 dB.

APPENDIX H:
SIGHTINGS AND DENSITIES OF MARINE MAMMALS BY DEPTH STRATUM AND NON-SEISMIC VS. SEISMIC PERIODS

APPENDIX H.1. Sightings and densities of marine mammals during **non-seismic periods in shallow water (<100 m)** in the Eastern Tropical Pacific Ocean off Central America during ETPCA ship surveys, 21 Nov. – 22 Dec. 2004. Non-seismic periods are periods before seismic started or periods >2 h after seismic ended. Species in italics are listed under the U.S. ESA as endangered. Survey effort was 41 km during Beaufort Wind Forces (Bf) ≤ 5 and 41 km with Bf ≤ 2.

Species	Number of sightings	Mean group size	Average density[a] corrected for *f*(0) and *g*(0) (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Delphinidae				
Rough-toothed dolphin	0	—	0.00	—
Tucuxi	0	—	0.00	—
Bottlenose dolphin	0	—	0.00	—
Pantropical Spotted dolphin	1	2.0	38.00	0.94
Spinner dolphin	0	—	0.00	—
Costa Rican spinner dolphin	0	—	0.00	—
Clymene dolphin	0	—	0.00	—
Striped dolphin	0	—	0.00	—
Short-beaked common dolphin	0	—	0.00	—
Unidentified common dolphin	0	—	0.00	—
Fraser's dolphin	0	—	0.00	—
Risso's dolphin	0	—	0.00	—
Unidentified dolphin	1	2.0	38.00	0.94
Melon-headed whale	0	—	0.00	—
Pygmy killer whale	0	—	0.00	—
False killer whale	0	—	0.00	—
Killer whale	0	—	0.00	—
Short-finned pilot whale	0	—	0.00	—
Total Delphinidae	**2**		**76.00**	
Physeteridae				
Sperm whale	*0*	—	*0.00*	—
Pygmy sperm whale	0	—	0.00	—
Dwarf sperm whale	0	—	0.00	—
Ziphiidae				
Tropical bottlenose whale	0	—	0.00	—
Pygmy beaked whale	0	—	0.00	—
Blainville's beaked whale	0	—	0.00	—
Mesoplodon sp. (unidentified)	0	—	0.00	—
Unidentified toothed whale				
Mysticetes				
Humpback whale	*0*	—	*0.00*	—
Minke whale	0	—	0.00	—
Bryde's whale	0	—	0.00	—
Sei whale	*0*	—	*0.00*	—
Fin whale	*0*	—	*0.00*	—
Blue whale	*0*	—	*0.00*	—
Unidentified whale	0	—	0.00	—
Total Non-Delphinids	**0**		**0.00**	
Total Cetaceans	**2**		**76**	

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - 0.162log$_e$n from Koski et al. (1998), but likely underestimates the true variability.

APPENDIX H.2. Sightings and densities of marine mammals **during non-seismic periods in intermediate water depths (100–1000 m)** in the Eastern Tropical Pacific Ocean off Central America during ETPCA ship surveys, 21 Nov. – 22 Dec. 2004. Non-seismic periods are periods before seismic started or periods >2 h after seismic ended. Species in italics are listed under the U.S. ESA as endangered. Survey effort was 279 km during Beaufort Wind Force (Bf) ≤ 5 and 165 km with Bf ≤ 2.

Species	**Number of sightings**	**Mean group size**	**Average density[a] corrected for *f*(0) and *g*(0) (# /1000 km²)**	
			Density	**CV [b]**
Odontocetes				
Delphinidae				
Rough-toothed dolphin	0	—	0.00	—
Tucuxi	0	—	0.00	—
Bottlenose dolphin	4	7.75	86.55	0.72
Pantropical Spotted dolphin	1	10.0	27.92	0.94
Spinner dolphin	0	—	0.00	—
Costa Rican spinner dolphin	0	—	0.00	—
Clymene dolphin	0	—	0.00	—
Striped dolphin	0	—	0.00	—
Short-beaked common dolphin	0	—	0.00	—
Unidentified common dolphin	0	—	0.00	—
Fraser's dolphin	0	—	0.00	—
Risso's dolphin	0	—	0.00	—
Unidentified dolphin	6	3.5	58.63	0.65
Melon-headed whale	0	—	0.00	—
Pygmy killer whale	0	—	0.00	—
False killer whale	0	—	0.00	—
Killer whale	0	—	0.00	—
Short-finned pilot whale	0	—	0.00	—
Total Delphinidae	**11**		**173.10**	
Physeteridae				
Sperm whale	*0*	—	*0.00*	—
Pygmy sperm whale	0	—	0.00	—
Dwarf sperm whale	0	—	0.00	—
Ziphiidae				
Tropical bottlenose whale	0	—	0.00	—
Pygmy beaked whale	0	—	0.00	—
Blainville's beaked whale	0	—	0.00	—
Mesoplodon sp. (unidentified)	0	—	0.00	—
Unidentified toothed whale				
Mysticetes				
Humpback whale	*0*	—	*0.00*	—
Minke whale	0	—	0.00	—
Bryde's whale	0	—	0.00	—
Sei whale	*0*	—	*0.00*	—
Fin whale	*0*	—	*0.00*	—
Blue whale	*0*	—	*0.00*	—
Unidentified whale	0	—	0.00	—
Total Non-Delphinids	**0**		**0.00**	
Total Cetaceans	**11**		**173.10**	

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

APPENDIX H.3. Sightings and densities of marine mammals **during non-seismic periods in deep water (>1000 m)** in the Eastern Tropical Pacific Ocean off Central America during the ETPCA surveys, 21 Nov. – 22 Dec. 2004. Non-seismic periods are periods before seismic started or periods >2 h after seismic ended. Species in italics are listed under the U.S. ESA as endangered. Survey effort was 289 km during Beaufort Wind Force (Bf) ≤ 5 and 85 m during Bf ≤ 2.

Species	**Number of sightings**	**Mean group size**	**Average density [a] corrected for *f*(0) and *g*(0) (# /1000 km^2)**	
			Density	**CV [b]**
Odontocetes				
Delphinidae				
Rough-toothed dolphin	0	—	0.00	—
Tucuxi	0	—	0.00	—
Bottlenose dolphin	2	9.5	51.21	0.83
Pantropical Spotted dolphin	1	10.0	26.95	0.94
Spinner dolphin	0	—	0.00	—
Costa Rican spinner dolphin	0	—	0.00	—
Clymene dolphin	0	—	0.00	—
Striped dolphin	0	—	0.00	—
Short-beaked common dolphin	1	45.0	40.17	0.94
Unidentified common dolphin	1	15.0	40.43	0.94
Fraser's dolphin	0	—	0.00	—
Risso's dolphin	1	25.0	22.32	0.94
Unidentified dolphin	3	40.3	71.07	0.76
Melon-headed whale	0	—	0.00	—
Pygmy killer whale	0	—	0.00	—
False killer whale	0	—	0.00	—
Killer whale	0	—	0.00	—
Short-finned pilot whale	3	8.3	67.38	0.76
Total Delphinidae	**12**		**319.53**	
Physeteridae				
Sperm whale	*0*	—	*0.00*	—
Pygmy sperm whale	0	—	0.00	—
Dwarf sperm whale	0	—	0.00	—
Ziphiidae				
Tropical bottlenose whale	0	—	0.00	—
Pygmy beaked whale	0	—	0.00	—
Blainville's beaked whale	0	—	0.00	—
Mesoplodon sp. (unidentified)	0	—	0.00	—
Unidentified toothed whale	1	4.0	5.38	0.94
Mysticetes				
Humpback whale	*0*	—	*0.00*	—
Minke whale	0	—	0.00	—
Bryde's whale	0	—	0.00	—
Sei whale	*0*	—	*0.00*	—
Fin whale	*0*	—	*0.00*	—
Blue whale	*0*	—	*0.00*	—
Unidentified whale	0	—	0.00	—
Total Non-Delphinids	**1**		**5.38**	
Total Cetaceans	**13**		**324.91**	

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - 0.162$\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

APPENDIX H.4. Sightings and densities of marine mammals during **seismic periods in shallow water (<100 m)** in the Eastern Tropical Pacific Ocean off Central America during ETPCA surveys, 21 Nov. – 22 Dec. 2004. Seismic periods are periods when one to three 45 or 105 in^3 GI gun were operating. Species in italics are listed under the U.S. ESA as endangered. Survey effort was 346 km during Beaufort Wind Force (Bf) ≤ 5 and 142 m during Bf ≤ 2.

Species	**Number of sightings**	**Mean group size**	**Average density [a] corrected for *f*(0) and *g*(0) (# /1000 km^2)**	
			Density	**CV [b]**
Odontocetes				
Delphinidae				
Rough-toothed dolphin	0	—	0.00	—
Tucuxi	0	—	0.00	—
Bottlenose dolphin	0	—	0.00	—
Pantropical Spotted dolphin	1	2.0	2.25	0.94
Spinner dolphin	0	—	0.00	—
Costa Rican spinner dolphin	0	—	0.00	—
Clymene dolphin	0	—	0.00	—
Striped dolphin	0	—	0.00	—
Short-beaked common dolphin	0	—	0.00	—
Unidentified common dolphin	0	—	0.00	—
Fraser's dolphin	0	—	0.00	—
Risso's dolphin	0	—	0.00	—
Unidentified dolphin	1	8.0	18.01	0.94
Melon-headed whale	0	—	0.00	—
Pygmy killer whale	0	—	0.00	—
False killer whale	0	—	0.00	—
Killer whale	0	—	0.00	—
Short-finned pilot whale	0	—	0.00	—
Total Delphinidae	**2**		**20.26**	
Physeteridae				
Sperm whale	*0*	—	*0.00*	—
Pygmy sperm whale	0	—	0.00	—
Dwarf sperm whale	0	—	0.00	—
Ziphiidae				
Tropical bottlenose whale	0	—	0.00	—
Pygmy beaked whale	0	—	0.00	—
Blainville's beaked whale	0	—	0.00	—
Mesoplodon sp. (unidentified)	0	—	0.00	—
Unidentified toothed whale				
Mysticetes				
Humpback whale	*9*	1.56	*15.72*	0.58
Minke whale	0	—	0.00	—
Bryde's whale	0	—	0.00	—
Sei whale	*0*	—	*0.00*	—
Fin whale	*0*	—	*0.00*	—
Blue whale	*0*	—	*0.00*	—
Unidentified whale	0	—	0.00	—
Total Non-Delphinids	**9**		**15.72**	
Total Cetaceans	**11**		**35.98**	

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - 0.162$\log_e$n from Koski et al. (1998), but likely underestimates the true variability.

APPENDIX H.5. Sightings and densities of marine mammals during **seismic periods in intermediate water depths (100–1000 m)** in the Eastern Tropical Pacific Ocean off Central America during the ETPCA survey, 21 Nov. – 22 Dec. 2004. Seismic periods are periods when one to three 45 or 105 in^3 GI gun were operating. Species in italics are listed under the U.S. ESA as endangered. Survey effort was 1433 km during Beaufort Wind Force (Bf) ≤ 5 and 197 km during Bf ≤ 2.

Species	Number of sightings	Mean group size	Average density [a] corrected for *f*(0) and *g*(0) (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Delphinidae				
Rough-toothed dolphin	0	—	0.00	—
Tucuxi	0	—	0.00	—
Bottlenose dolphin	1	4.0	2.17	0.94
Pantropical Spotted dolphin	4	46.5	26.04	0.72
Spinner dolphin	3	450.0	137.54	0.76
Costa Rican spinner dolphin	0	—	0.00	—
Clymene dolphin	0	—	0.00	—
Striped dolphin	0	—	0.00	—
Short-beaked common dolphin	0	—	0.00	—
Unidentified common dolphin	0	—	0.00	—
Fraser's dolphin	0	—	0.00	—
Risso's dolphin	0	—	0.00	—
Unidentified dolphin	12	5.5	21.34	0.54
Melon-headed whale	0	—	0.00	—
Pygmy killer whale	0	—	0.00	—
False killer whale	0	—	0.00	—
Killer whale	0	—	0.00	—
Short-finned pilot whale	0	—	0.00	—
Total Delphinidae	**20**		**187.09**	
Physeteridae				
Sperm whale	*0*	—	*0.00*	—
Pygmy sperm whale	0	—	0.00	—
Dwarf sperm whale	0	—	0.00	—
Ziphiidae				
Tropical bottlenose whale	0	—	0.00	—
Pygmy beaked whale	0	—	0.00	—
Blainville's beaked whale	0	—	0.00	—
Mesoplodon sp. (unidentified)	0	—	0.00	—
Unidentified toothed whale	0	—	0.00	—
Mysticetes				
Humpback whale	*2*	1.0	*0.54*	0.83
Minke whale	0	—	0.00	—
Bryde's whale	0	—	0.00	—
Sei whale	*0*	—	*0.00*	—
Fin whale	*0*	—	*0.00*	—
Blue whale	*0*	—	*0.00*	—
Unidentified whale	3	1.0	0.81	0.76
Total Non-Delphinids	**5**		**1.35**	
Total Cetaceans	**25**		**188.44**	

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

APPENDIX H.6. Sightings and densities of marine mammals **during seismic periods in deep water (>1000 m)** in the Eastern Tropical Pacific Ocean off Central America during ship surveys, 21 Nov. – 22 Dec. 2004. Seismic periods are periods when one to three 45 or 105 in^3 GI gun were operating. Species in italics are listed under the U.S. ESA as endangered. Survey effort was 345 km during Beaufort Wind Force (Bf) ≤ 5 and 56 km during Bf ≤ 2.

Species	**Number of sightings**	**Mean group size**	**Average density [a] corrected for *f*(0) and *g*(0) (# /1000 km^2)**	
			Density	**CV [b]**
Odontocetes				
Delphinidae				
Rough-toothed dolphin	0	—	0.00	—
Tucuxi	0	—	0.00	—
Bottlenose dolphin	1	15.0	33.87	0.94
Pantropical Spotted dolphin	0	—	0.00	—
Spinner dolphin	0	—	0.00	—
Costa Rican spinner dolphin	0	—	0.00	—
Clymene dolphin	0	—	0.00	—
Striped dolphin	0	—	0.00	—
Short-beaked common dolphin	0	—	0.00	—
Unidentified common dolphin	0	—	0.00	—
Fraser's dolphin	0	—	0.00	—
Risso's dolphin	0	—	0.00	—
Unidentified dolphin	3	2.7	18.06	0.76
Melon-headed whale	0	—	0.00	—
Pygmy killer whale	0	—	0.00	—
False killer whale	1	12.0	27.09	0.94
Killer whale	0	—	0.00	—
Short-finned pilot whale	1	5.0	11.29	0.94
Total Delphinidae	**6**		**90.31**	
Physeteridae				
Sperm whale	*0*	—	*0.00*	—
Pygmy sperm whale	0	—	0.00	—
Dwarf sperm whale	0	—	0.00	—
Ziphiidae				
Tropical bottlenose whale	0	—	0.00	—
Pygmy beaked whale	0	—	0.00	—
Blainville's beaked whale	0	—	0.00	—
Mesoplodon sp. (unidentified)	0	—	0.00	—
Unidentified toothed whale				
Mysticetes				
Humpback whale	*0*	—	*0.00*	—
Minke whale	0	—	0.00	—
Bryde's whale	0	—	0.00	—
Sei whale	*0*	—	*0.00*	—
Fin whale	*0*	—	*0.00*	—
Blue whale	*0*	—	*0.00*	—
Unidentified whale	0	—	0.00	—
Total Non-Delphinids	**0**		**0.00**	
Total Cetaceans	**6**		**90.31**	

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

APPENDIX H.7. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that would have been exposed to seismic sounds ≥160 dB (and ≥170 dB) in the Eastern Tropical Pacific Ocean off Central America **if no animals had moved away from the active seismic vessel**, 21 Nov. – 22 Dec. 2004. Based on calculated densities[a] in **non-seismic periods** (Appendices H-1 to H-3). The sound sources were 1 to 3 GI guns with total generator volumes of 45–315 in^3. Received levels of GI gun sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration). Species in italics are listed under the U.S ESA as endangered.

Species/species group	Numbers of exposures [b]								Minimum number of individuals [b]							
Water depth (m)	<100		100-1000		>1000		All depths		<100		100-1000		>1000		All depths	
Area in km^2 ensonified to ≥160 dB (≥170 dB)	4168	(2052)	6274	(1968)	1302	(406)			3671	(1961)	5501	(1880)	1235	(396)		
Odontocetes																
Delphinidae																
Rough-toothed dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Tucuxi	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Bottlenose dolphin	0	()	543	(170)	67	(21)	610	(191)	0	()	476	(163)	63	(20)	539	(183)
Pantropical Spotted dolphin	158	(78)	175	(55)	35	(11)	369	(144)	139	(75)	154	(52)	33	(11)	326	(138)
Spinner dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Costa Rican spinner dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Clymene dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Striped dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Short-beaked common dolphin	0	()	0	()	52	(16)	52	(16)	0	()	0	()	50	(16)	50	(16)
Unidentified common dolphin	0	()	0	()	53	(16)	53	(16)	0	()	0	()	50	(16)	50	(16)
Fraser's dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Risso's dolphin	0	()	0	()	29	(9)	29	(9)	0	()	0	()	28	(9)	28	(9)
Unidentified dolphin	158	(78)	368	(115)	93	(29)	619	(222)	139	(75)	323	(110)	88	(28)	550	(213)
Melon-headed whale	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Pygmy killer whale	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
False killer whale	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Killer whale	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Short-finned pilot whale	0	()	0	()	88	(27)	88	(27)	0	()	0	()	83	(27)	83	(27)
Total Delphinidae	**317**	**(156)**	**1086**	**(341)**	**416**	**(130)**	**1819**	**(626)**	**279**	**(149)**	**952**	**(325)**	**395**	**(127)**	**1626**	**(601)**
Physeteridae																
Sperm whale	0		0		0		0		0		0		0		0	
Pygmy sperm whale	0		0		0		0		0		0		0		0	
Dwarf sperm whale	0		0		0		0		0		0		0		0	
Ziphiidae																
Tropical bottlenose whale	0		0		0		0		0		0		0		0	
Pygmy beaked whale	0		0		0		0		0		0		0		0	
Blainville's beaked whale	0		0		0		0		0		0		0		0	
Mesoplodon sp. (unidentified)	0		0		0		0		0		0		0		0	
Unidentified toothed whale	0		0		7		7		0		0		7		7	
Mysticetes																
Humpback whale	0		0		0		0		0		0		0		0	
Minke whale	0		0		0		0		0		0		0		0	
Bryde's whale	0		0		0		0		0		0		0		0	
Sei whale	0		0		0		0		0		0		0		0	
Fin whale	0		0		0		0		0		0		0		0	
Blue whale	0		0		0		0		0		0		0		0	
Unidentified whale	0		0		0		0		0		0		0		0	
Total Non-Delphinids	**0**		**0**		**7**		**7**		**0**		**0**		**7**		**7**	
Total Cetaceans	**317**		**1086**		**423**		**1826**		**279**		**952**		**401**		**1632**	

[a] Values for *f* (0) and *g* (0) are from Koski et al. (1998) and Barlow (1999).

[b] Slight apparent discrepancies in totals result from rounding to integers.

APPENDIX H.8. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that were exposed to seismic sounds ≥160 dB (and ≥170 dB) in the Eastern Tropical Pacific Ocean during the ETPCA surveys, 21 Nov. – 22 Dec. 2004. Based on calculated densities[a] in **seismic periods** (Appendices H-4 to H-6). The sound sources were 1 to 3 GI guns with total generator volumes of 45–315 in^3. Received levels of GI gun sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration). Species in italics are listed under the U.S. ESA as endangered.

Species/species group	**Numbers of exposures** [b]								**Minimum number of individuals** [b]							
Water depth (m)	**<100**		**100-1000**		**>1000**		**All depths**		**<100**		**100-1000**		**>1000**		**All depths**	
Area in km^2 ensonified to ≥160 dB (≥170 dB)	4168	(2052)	6274	(1968)	1302	(406)			3671	(1961)	5501	(1880)	1235	(396)		
Odontocetes																
Delphinidae																
Rough-toothed dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Tucuxi	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Bottlenose dolphin	0	()	14	(4)	44	(14)	58	(18)	0	()	12	(4)	42	(13)	54	(17)
Pantropical Spotted dolphin	9	(5)	163	(51)	0	()	173	(56)	8	(4)	143	(49)	0	()	152	(53)
Spinner dolphin	0	()	863	(271)	0	()	863	(271)	0	()	757	(259)	0	()	757	(259)
Costa Rican spinner dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Clymene dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Striped dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Short-beaked common dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Unidentified common dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Fraser's dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Risso's dolphin	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Unidentified dolphin	75	(37)	134	(42)	24	(7)	232	(86)	66	(35)	117	(40)	22	(7)	206	(83)
Melon-headed whale	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Pygmy killer whale	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
False killer whale	0	()	0	()	35	(11)	35	(11)	0	()	0	()	33	(11)	33	(11)
Killer whale	0	()	0	()	0	()	0	()	0	()	0	()	0	()	0	()
Short-finned pilot whale	0	()	0	()	15	(5)	15	(5)	0	()	0	()	14	(4)	14	(4)
Total Delphinidae	**84**	**(42)**	**1174**	**(368)**	**118**	**(37)**	**1376**	**(446)**	**74**	**(40)**	**1029**	**(352)**	**112**	**(36)**	**1215**	**(427)**
Physeteridae	0		0		0		0		0		0		0		0	
Sperm whale	0		0		0		0		0		0		0		0	
Pygmy sperm whale	0		0		0		0		0		0		0		0	
Dwarf sperm whale	0		0		0		0		0		0		0		0	
Ziphiidae	0		0		0		0		0		0		0		0	
Tropical bottlenose whale	0		0		0		0		0		0		0		0	
Pygmy beaked whale	0		0		0		0		0		0		0		0	
Blainville's beaked whale	0		0		0		0		0		0		0		0	
Mesoplodon sp. (unidentified)	0		0		0		0		0		0		0		0	
Unidentified toothed whale	0		0		0		0		0		0		0		0	
Mysticetes																
Humpback whale	66		3		0		69		58		3		0		61	
Minke whale	0		0		0		0		0		0		0		0	
Bryde's whale	0		0		0		0		0		0		0		0	
Sei whale	0		0		0		0		0		0		0		0	
Fin whale	0		0		0		0		0		0		0		0	
Blue whale	0		0		0		0		0		0		0		0	
Unidentified whale	0		5		0		5		0		4		0		4	
Total Non-Delphinids	**66**		**8**		**0**		**74**		**58**		**7**		**0**		**65**	
Total Cetaceans	**150**		**1182**		**118**		**1450**		**132**		**1037**		**112**		**1280**	

[a] Values for *f* (0) and *g* (0) are from Koski et al. (1998) and Barlow (1999).

[b] Slight apparent discrepancies in totals result from rounding to integers.

APPENDIX H.9. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that would have been exposed to seismic sounds ≥180 dB (≥190 dB for less responsive species) in the Eastern Tropical Pacific Ocean off Central America during the ETPCA surveys **if no animals had moved away from the active seismic vessel**, 21 Nov. – 22 Dec. 2004. Based on calculated densities[a] during seismic periods (Appendices H-4 to H-6). The sound sources were 1 to 3 GI guns with generator volumes of 45 to 315 in^3. Received levels of GI gun sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration). Species in italics are listed under the U.S. ESA as endangered.

Species/species group	Numbers of exposures [b]								Minimum number of individuals [b]							
Water depth (m)	<100		100-1000		>1000		All depths		<100		100-1000		>1000		All depths	
Area in km^2 ensonified to ≥180 dB (≥190 dB)	866	(573)	602	(187)	124	(40)			851	(566)	591	(186)	122	(39)		
Odontocetes																
Delphinidae																
Rough-toothed dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Tucuxi	0	(0)	0	()	0	()	0	()	0	(0)	0	()	0	()	0	()
Bottlenose dolphin	0	(0)	1	()	4	(1)	6	(2)	0	(0)	1	()	4	(1)	5	(2)
Pantropical Spotted dolphin	2	(1)	16	(5)	0	(0)	18	(6)	2	(1)	15	(5)	0	(0)	17	(6)
Spinner dolphin	0	(0)	83	(26)	0	(0)	83	(26)	0	(0)	81	(26)	0	(0)	81	(26)
Costa Rican spinner dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Clymene dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Striped dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Short-beaked common dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Unidentified common dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Fraser's dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Risso's dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Unidentified dolphin	16	(10)	13	(4)	2	(1)	31	(15)	15	(10)	13	(4)	2	(1)	30	(15)
Melon-headed whale	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Pygmy killer whale	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
False killer whale	0	(0)	0	(0)	3	(1)	3	(1)	0	(0)	0	(0)	3	(1)	3	(1)
Killer whale	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Short-finned pilot whale	0	(0)	0	(0)	1	()	1	()	0	(0)	0	(0)	1	()	1	()
Total Delphinidae	**18**	**(12)**	**113**	**(35)**	**11**	**(4)**	**141**	**(50)**	**17**	**(11)**	**111**	**(35)**	**11**	**(4)**	**139**	**(50)**
Physeteridae	0		0		0		0		0		0		0		0	
Sperm whale	0		0		0		0		0		0		0		0	
Pygmy sperm whale	0		0		0		0		0		0		0		0	
Dwarf sperm whale	0		0		0		0		0		0		0		0	
Ziphiidae																
Tropical bottlenose whale	0		0		0		0		0		0		0		0	
Pygmy beaked whale	0		0		0		0		0		0		0		0	
Blainville's beaked whale	0		0		0		0		0		0		0		0	
Mesoplodon sp. (unidentified)	0		0		0		0		0		0		0		0	
Unidentified toothed whale	0		0		0		0		0		0		0		0	
Mysticetes																
Humpback whale	14		0		0		14		13		0		0		14	
Minke whale	0		0		0		0		0		0		0		0	
Bryde's whale	0		0		0		0		0		0		0		0	
Sei whale	0		0		0		0		0		0		0		0	
Fin whale	0		0		0		0		0		0		0		0	
Blue whale	0		0		0		0		0		0		0		0	
Unidentified whale	0		0		0		0		0		0		0		0	
Total Non-Delphinids	**14**		**1**		**0**		**14**		**13**		**1**		**0**		**14**	
Total Cetaceans	**31**		**113**		**11**		**156**		**31**		**111**		**11**		**153**	

[a] Values for $f(0)$ and $g(0)$ are from Koski et al. (1998) and Barlow (1999).

[b] Slight apparent discrepancies in totals result from rounding to integers.

APPENDIX I:

ADDITIONAL SEA TURTLE DATA

APPENDIX I.1. Sea turtle sightings made from the *Ewing* during the ETPCA seismic survey (including transits to and from port) in the Eastern Tropical Pacific Ocean off Central America, 21 Nov. – 22 Dec. 2004. All sea turtles were sighted visually. Dead sea turtles are indicated as "DE" in the "Initial Behavior" column.

SPECIES	Grp Size	Day in 2004	Time (GMT)	Latitude (°N)	Longitude (°W)	Sighting Distance (m) (Distance from FB/B to sighting)	CPA[a] (m) (Distance from turtle to GI gun(s))	Initial Move-ment[b]	Initial Behavior[c]	BF[d]	Useable[e] Y=yes N=no	Water depth[f] (m)	Vessel Activ.[g]	# GI Guns On	Array Vol. (in^3)	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)
Unidentified sea turtle	1	21-Nov	20:17	9.5591	85.3833	1200	65	NO	LG	2	Y	100-1000	OT	0	0	L	
Unidentified sea turtle	1	21-Nov	21:55	9.7407	85.6815	689	689	NO	LG	2	Y	100-1000	OT	0	0	L	
Unidentified sea turtle	1	21-Nov	22:06	9.7627	85.7175	533	533	NO	LG	2	Y	100-1000	OT	0	0	L	
Unidentified sea turtle	1	22-Nov	13:47	10.3814	86.1001	25	25	NO	LG	4	Y	100-1000	LS	3	135	L	
Unidentified sea turtle	2	23-Nov	16:14	10.5534	85.8749	200	60	NO	LG	2	Y	79	LS	3	135	L	SZ
Unidentified sea turtle	1	23-Nov	16:55	10.5480	85.914	15	10	NO	LG	2	Y	87	RU	88	99	L	SZ
Unidentified sea turtle	1	23-Nov	16:57	10.5513	85.9139	250	200	NO	LG	2	Y	87	OT	0	0	L	
Unidentified sea turtle	1	23-Nov	18:16	10.6074	85.8416	20	20	NO	LG	2	Y	78	SZ	0	0	L	SZ
Unidentified sea turtle	2	23-Nov	18:58	10.5657	85.8624	215	215	NO	LG	2	N	81	OT	0	0	L	
Olive ridley sea turtle	1	23-Nov	19:11	10.5549	85.8731	10	10	NO	LG	2	N	80	OT	0	0	L	
Unidentified sea turtle	1	23-Nov	19:18	10.5490	85.8793	389	389	NO	LG	2	N	80	OT	0	0	L	
Green sea turtle	1	23-Nov	20:16	10.4977	85.9314	20	20	NO	LG	2	Y	85	OT	0	0	L	
Unidentified sea turtle	1	23-Nov	20:56	10.4624	85.9673	50	10	NO	LG	2	Y	86	OT	0	0	L	
Unidentified sea turtle	1	23-Nov	21:08	10.4519	85.9781	20	20	NO	LG	2	Y	87	OT	0	0	L	
Olive ridley sea turtle	1	23-Nov	22:22	10.3864	86.0447	5	5	NO	LG	2	Y	104	OT	0	0	L	
Unidentified sea turtle	1	24-Nov	19:51	10.1820	86.3662	928	928	SA	SW	1	Y	2540	SH	2	90	L	
Unidentified sea turtle	1	25-Nov	14:42	10.4134	86.0439	277	270	NO	LG	2	Y	103	PD	2	90	L	PD
Unidentified sea turtle	1	25-Nov	15:24	10.4511	86.0057	928	736	NO	LG	2	Y	93	LS	3	135	L	SZ
Unidentified sea turtle	1	25-Nov	15:43	10.4684	85.9877	1017	650	NO	LG	2	Y	90	SZ	0	0	L	SZ
Unidentified sea turtle	1	25-Nov	17:28	10.5484	85.8884	3151	3151	NO	DE	2	N	87	SH	2	90	L	
Leatherback sea turtle	1	25-Nov	17:53	10.5419	85.8548	10	0	ST	SW	2	Y	69	SZ	0	0	L	SZ
Olive ridley sea turtle	1	25-Nov	17:58	10.5408	85.8494	5	0	ST	SW	2	N	67	OT	0	0	L	
Green sea turtle	1	25-Nov	18:42	10.5723	85.8338		Dead	NO	DE	4	N	76	LS	3	135	L	
Olive ridley sea turtle	1	25-Nov	19:58	10.6413	85.9	5	0	ST	SW	4	Y	91	SZ	0	0	L	SZ
Unidentified sea turtle	1	25-Nov	20:23	10.6625	85.9208	100	20	SA	SW	4	N	97	OT	0	0	L	
Unidentified sea turtle	2	25-Nov	21:18	10.7122	85.9689	200	30	NO	OT	4	Y	119	OT	0	0	L	SZ
Olive ridley sea turtle	1	26-Nov	18:18	11.8894	87.111	40	127	NO	LG	4	Y	114	SZ	0	0	L	SZ
Olive ridley sea turtle	1	26-Nov	18:18	11.8895	87.111	50	50	ST	SW	4	Y	114	OT	0	0	L	
Olive ridley sea turtle	1	26-Nov	18:41	11.9105	87.1315	75	75	NO	LG	4	N	115	OT	0	0	L	
Olive ridley sea turtle	1	26-Nov	18:45	11.9134	87.1345	150	150	NO	LG	4	N	115	OT	0	0	L	
Olive ridley sea turtle	1	26-Nov	20:50	12.0262	87.2442	20	5	NO	LG	3	Y	117	OT	0	0	L	SZ
Unidentified sea turtle	1	26-Nov	21:12	12.0460	87.2638	15	10	NO	LG	3	N	116	OT	0	0	L	
Unidentified sea turtle	1	26-Nov	21:25	12.0587	87.2751	25	10	NO	LG	3	N	117	OT	0	0	L	
Olive ridley sea turtle	1	26-Nov	21:34	12.0690	87.2764	75	10	NO	LG	3	N	115	OT	0	0	L	
Unidentified sea turtle	1	26-Nov	21:47	12.0805	87.2651	80	15	NO	LG	3	N	113	OT	0	0	L	

SPECIES	Grp Size	Day in 2004	Time (GMT)	Latitude (°N)	Longitude (°W)	Sighting Distance (m) (Distance from FB/B to sighting)	CPA[a] (m) (Distance from turtle to GI gun(s))	Initial Move-ment[b]	Initial Behavior[c]	BF[d]	Useable[e] Y=yes N=no	Water depth[f] (m)	Vessel Activ.[g]	# GI Guns On	Array Vol. (in^3)	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)
Unidentified sea turtle	1	26-Nov	21:52	12.0840	87.2597	50	15	NO	LG	3	N	111	OT	0	0	L	
Unidentified sea turtle	1	26-Nov	21:56	12.0867	87.2558	65	20	NO	LG	3	N	110	OT	0	0	L	
Unidentified sea turtle	1	26-Nov	21:59	12.0886	87.2529	60	10	NO	LG	3	N	109	OT	0	0	L	
Olive ridley sea turtle	1	27-Nov	14:40	11.9894	87.0098	150	100	NO	LG	3	Y	89	SZ	0	0	L	SZ
Unidentified sea turtle	1	27-Nov	15:08	12.0165	87.036	60	40	NO	LG	3	N	91	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	15:58	12.0632	87.0812	100	10	NO	DE	2	N	89	LS	3	135	L	
Olive ridley sea turtle	2	27-Nov	16:02	12.0671	87.085	150	35	NO	OT	2	Y	91	SZ	0	0	L	SZ
Unidentified sea turtle	1	27-Nov	16:08	12.0719	87.0898	1017	900	NO	LG	2	N	90	OT	0	0	L	
Olive ridley sea turtle	1	27-Nov	16:23	12.0859	87.1033	250	60	NO	LG	2	N	90	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	16:55	12.1145	87.1309	854	650	NO	LG	2	Y	87	SZ	0	0	L	SZ
Unidentified sea turtle	1	27-Nov	17:07	12.1258	87.142	105	10	SA	SW	2	N	87	OT	0	0	L	
Olive ridley sea turtle	1	27-Nov	17:12	12.1290	87.1471	175	35	NO	LG	2	N	85	OT	0	0	L	
Olive ridley sea turtle	1	27-Nov	17:17	12.1298	87.1532	210	20	SA	SW	2	N	88	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	17:22	12.1282	87.1585	1125	800	NO	LG	2	N	89	OT	0	0	L	
Olive ridley sea turtle	1	27-Nov	17:25	12.1257	87.1619	736	736	NO	LG	2	N	90	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	17:34	12.1181	87.1709	253	253	NO	LG	2	N	92	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	17:37	12.1162	87.1733	343	343	NO	LG	2	N	93	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	18:21	12.0722	87.1546	1258	1258	NO	LG	2	Y	100	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:33	12.0607	87.1431	1427	1017	NO	LG	1	Y	101	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:36	12.0587	87.1411	2410	1258	NO	LG	1	Y	100	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:47	12.0478	87.1308	928	928	NO	LG	1	Y	100	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:47	12.0477	87.1308	1958	1958	NO	LG	1	Y	100	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:47	12.0477	87.1307	2410	2410	NO	LG	1	Y	100	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:47	12.0477	87.1307	3151	3151	NO	LG	1	Y	100	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:47	12.0477	87.1307	928	549	NO	LG	1	Y	100	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:47	12.0477	87.1307	533	533	NO	LG	1	Y	100	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:47	12.0477	87.1307	533	533	NO	LG	1	Y	100	LS	3	135	L	
Unidentified sea turtle	1	27-Nov	18:53	12.0426	87.1258	200	200	NO	LG	1	Y	100	SZ	0	0	L	SZ
Unidentified sea turtle	1	27-Nov	18:55	12.0404	87.1236	389	389	NO	LG	1	N	100	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	18:57	12.0384	87.1216	1958	1958	NO	LG	1	N	102	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	18:57	12.0384	87.1216	1650	1650	NO	LG	1	N	104	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	19:07	12.0292	87.1128	4633	4633	NO	LG	1	N	104	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	19:12	12.0246	87.1083	3151	3151	NO	LG	1	N	104	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	19:12	12.0246	87.1083	4633	4633	NO	LG	1	N	101	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	19:45	11.9928	87.0776	389	329	NO	LG	1	Y	102	PD	1	45	L	PD
Olive ridley sea turtle	1	27-Nov	19:47	11.9910	87.0758	20	95	NO	LG	1	Y	103	SZ	0	0	L	SZ
Olive ridley sea turtle	1	27-Nov	19:55	11.9829	87.0679	60	25	NO	LG	1	N	102	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	20:06	11.9729	87.0581	3151	3151	NO	LG	1	N	102	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	20:08	11.9712	87.0565	928	928	NO	LG	1	N	103	OT	0	0	L	
Unidentified sea turtle	2	27-Nov	20:09	11.9703	87.0556	2729	2729	NO	LG	1	N	102.6	OT	0	0	L	
Unidentified sea turtle	1	27-Nov	20:10	11.9695	87.0549	3739	3739	NO	LG	1	N	102.5	OT	0	0	L	
Unidentified sea turtle	2	27-Nov	20:11	11.9681	87.0536	1958	1427	NO	LG	1	N	102.9	OT	0	0	L	
Olive ridley sea turtle	2	27-Nov	21:58	11.8664	86.9552	300	123	NO	SW	1	Y	102	SZ	0	0	L	SZ
Unidentified sea turtle	2	27-Nov	22:40	11.8268	86.917	533	150	NO	OT	2	Y	101	PD	1	45	L	PD
Unidentified sea turtle	1	28-Nov	3:23	11.9488	87.0994	60	107	NO	LG	1	N	108	SZ	0	0	D	SZ
Unidentified sea turtle	1	30-Nov	21:37	11.8827	87.3476	389	350	NO	LG	2	Y	128	PD	1	45	L	PD
Unidentified sea turtle	1	30-Nov	22:00	11.9039	87.3265	500	500	NO	LG	2	Y	125	LS	3	135	L	
Unidentified sea turtle	1	1-Dec	21:22	11.6381	87.4837	5	92	ST	SW	3	Y	1049	SZ	0	0	L	SZ

SPECIES	Grp Size	Day in 2004	Time (GMT)	Latitude (°N)	Longitude (°W)	Sighting Distance (m) (Distance from FB/B to sighting)	CPA[a] (m) (Distance from turtle to GI gun(s))	Initial Move-ment[b]	Initial Behavior[d]	BF[d]	Useable[e] Y=yes N=no	Water depth[f] (m)	Vessel Activ.[g]	# GI Guns On	Array Vol. (in^3)	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)
Unidentified sea turtle	1	2-Dec	13:08	11.7891	87.2839	5	92	NO	LG	5	Y	134	SZ	0	0	L	SZ
Unidentified sea turtle	1	2-Dec	19:18	11.4771	87.6507	134	Dead	NO	DE	3	N	2626	SH	2	210	L	
Unidentified sea turtle	1	4-Dec	20:10	11.5900	87.3753	175	125	SA	SW	5	Y	676	SZ	0	0	L	SZ
Unidentified sea turtle	1	4-Dec	20:13	11.5922	87.3731	55	30	NO	LG	5	N	664	OT	0	0	L	
Unidentified sea turtle	1	4-Dec	20:31	11.6050	87.3606	130	170	NO	LG	5	Y	536	SZ	0	0	L	SZ
Olive ridley sea turtle	1	4-Dec	20:58	11.6248	87.341	85	104	NO	LG	5	Y	396	SZ	0	0	L	SZ
Unidentified sea turtle	1	4-Dec	21:42	11.6582	87.3084	200	150	NO	LG	5	Y	224	PD	1	105	L	PD
Unidentified sea turtle	1	4-Dec	22:39	11.7008	87.2664	232	100	SA	SW	5	Y	159	LS	3	315	L	
Olive ridley sea turtle	1	4-Dec	22:40	11.7018	87.2654	5	87	NO	LG	5	Y	158	SZ	0	0	L	SZ
Unidentified sea turtle	1	5-Dec	20:03	11.4668	87.3922	50	92	NO	LG	5	Y	967	SZ	0	0	L	SZ
Unidentified sea turtle	1	5-Dec	20:20	11.4785	87.3808	10	97	SA	SW	5	Y	907	SZ	0	0	L	SZ
Olive ridley sea turtle	1	5-Dec	22:19	11.5613	87.2996	135	135	SA	SW	4	Y	422	PD	1	45	L	PD
Unidentified sea turtle	1	5-Dec	22:26	11.5665	87.2944	20	98	SP	SW	4	Y	395	SZ	0	0	L	SZ
Olive ridley sea turtle	1	6-Dec	13:10	11.7122	87.0997	30	100	NO	LG	3	Y	128	SZ	0	0	L	SZ
Olive ridley sea turtle	1	6-Dec	14:09	11.6565	87.1544	45	107	NO	LG	3	Y	116	SZ	0	0	L	SZ
Olive ridley sea turtle	1	6-Dec	15:46	11.5573	87.2519	30	97	NO	LG	3	Y	274	SZ	0	0	L	SZ
Unidentified sea turtle	1	6-Dec	16:09	11.5334	87.2753	200	156	NO	LG	3	Y	420	SZ	0	0	L	SZ
Olive ridley sea turtle	1	6-Dec	17:04	11.4787	87.3289	25	92	NO	LG	3	Y	746	SZ	0	0	L	SZ
Olive ridley sea turtle	1	6-Dec	17:12	11.4706	87.3368	225	200	NO	LG	3	Y	780	PD	1	45	L	PD
Olive ridley sea turtle	1	6-Dec	17:55	11.4287	87.3781	200	218	NO	LG	3	Y	1034	PD	1	45	L	PD
Olive ridley sea turtle	1	6-Dec	18:16	11.4082	87.3978	180	150	NO	LG	3	Y	1176	PD	1	45	L	PD
Olive ridley sea turtle	1	7-Dec	14:35	11.7499	86.959	100	170	NO	LG	2	Y	111	SZ	0	0	L	SZ
Unidentified sea turtle	1	7-Dec	14:51	11.7365	86.9723	450	420	NO	LG	2	Y	111	LS	3	135	L	
Olive ridley sea turtle	1	7-Dec	14:58	11.7305	86.9782	50	117	NO	LG	2	Y	113	SZ	0	0	L	SZ
Olive ridley sea turtle	1	7-Dec	15:04	11.7257	86.9829	30	117	NO	LG	3	Y	113	SZ	0	0	L	SZ
Unidentified sea turtle	1	7-Dec	15:15	11.7160	86.9923	100	100	SP	SW	3	Y	114	SZ	0	0	L	SZ
Olive ridley sea turtle	1	7-Dec	15:20	11.7117	86.9966	60	117	SP	SW	3	Y	115	SZ	0	0	L	SZ
Unidentified sea turtle	1	7-Dec	16:09	11.6708	87.0368	15	95	SP	SW	3	Y	125	SZ	0	0	L	SZ
Olive ridley sea turtle	1	8-Dec	12:19	11.8932	87.5703	10	95	NO	LG	4	Y	169	SZ	0	0	L	SZ
Olive ridley sea turtle	1	8-Dec	15:26	12.0851	87.6823	5	92	NO	LG	4	Y	157	SZ	0	0	L	SZ
Olive ridley sea turtle	1	8-Dec	16:41	12.1393	87.7352	85	118	SP	SW	4	Y	142	SZ	0	0	L	SZ
Olive ridley sea turtle	1	8-Dec	16:43	12.1409	87.7368	75	20	NO	LG	4	N	141	OT	0	0	L	
Olive ridley sea turtle	1	8-Dec	17:09	12.1604	87.756	130	170	NO	LG	4	Y	138	SZ	0	0	L	SZ
Olive ridley sea turtle	1	8-Dec	17:14	12.1638	87.7593	100	20	SP	SW	4	N	137	OT	0	0	L	
Olive ridley sea turtle	1	8-Dec	18:13	12.2089	87.8033	277	200	NO	LG	4	Y	128	PD	1	45	L	PD
Olive ridley sea turtle	1	8-Dec	18:22	12.2152	87.8094	100	132	NO	LG	4	Y	127	SZ	0	0	L	SZ
Olive ridley sea turtle	1	8-Dec	18:48	12.2354	87.8292	200	113	NO	LG	4	Y	123	SZ	0	0	L	SZ
Olive ridley sea turtle	1	8-Dec	19:26	12.2646	87.8578	50	95	NO	LG	3	Y	121	SZ	0	0	L	SZ
Olive ridley sea turtle	1	8-Dec	19:37	12.2728	87.8658	200	170	NO	LG	3	Y	120	SZ	0	0	L	SZ
Unidentified sea turtle	1	10-Dec	14:51	12.0986	87.5684	80	116	NO	LG	4	Y	129	SZ	0	0	L	SZ
Unidentified sea turtle	1	10-Dec	15:18	12.0743	87.5446	105	105	NO	LG	4	N	131	SZ	0	0	L	SZ
Olive ridley sea turtle	1	10-Dec	16:02	12.0342	87.5055	70	102	NO	LG	4	N	134	SZ	0	0	L	SZ
Olive ridley sea turtle	1	10-Dec	17:16	11.9674	87.4407	200	200	NO	LG	4	Y	134	PD	1	45	L	PD
Olive ridley sea turtle	1	10-Dec	17:42	11.9438	87.4176	30	107	NO	LG	4	Y	134	SZ	0	0	L	SZ
Olive ridley sea turtle	1	10-Dec	19:09	11.8668	87.3427	100	132	SP	DI	2	Y	131	SZ	0	0	L	SZ
Olive ridley sea turtle	1	10-Dec	19:39	11.8411	87.3176	50	113	NO	LG	2	Y	130	SZ	0	0	L	SZ
Olive ridley sea turtle	1	10-Dec	19:49	11.8333	87.3101	232	200	NO	LG	2	N	130	PD	1	45	L	PD
Olive ridley sea turtle	1	14-Dec	17:36	11.2765	86.3908	40	87	NO	LG	6	Y	113	SZ	0	0	L	SZ
Olive ridley sea turtle	1	14-Dec	19:46	11.3889	86.2846	120	144	NO	LG	7	Y	69	SZ	0	0	L	SZ

SPECIES	Grp Size	Day in 2004	Time (GMT)	Latitude (°N)	Longitude (°W)	Sighting Distance (m) (Distance from FB/B to sighting)	CPA[a] (m) (Distance from turtle to GI gun(s))	Initial Move-ment[b]	Initial Behavior[c]	BF[d]	Useable[e] Y=yes N=no	Water depth[f] (m)	Vessel Activ.[g]	# GI Guns On	Array Vol. (in^3)	Light or Dark (L or D)	Mitig. Measure Taken (SZ, PD, None)
Unidentified sea turtle	1	16-Dec	13:29	11.3854	86.7489	10	95	NO	LG	5	Y	150	SZ	0	0	L	SZ
Olive ridley sea turtle	1	16-Dec	15:55	11.5245	86.884	110	123	NO	LG	4	Y	128	SZ	0	0	L	SZ
Olive ridley sea turtle	1	16-Dec	16:40	11.5665	86.925	120	144	SP	SW	4	Y	121	SZ	0	0	L	SZ
Olive ridley sea turtle	1	16-Dec	17:17	11.6019	86.9591	418	400	NO	LG	4	Y	119	LS	3	135	L	
Olive ridley sea turtle	1	16-Dec	17:23	11.6074	86.9645	120	100	NO	LG	4	Y	121	SZ	0	0	L	SZ
Olive ridley sea turtle	1	16-Dec	18:02	11.6464	87.0026	250	328	SA	SW	4	Y	120.1	PD	1	45	L	PD
Olive ridley sea turtle	1	16-Dec	18:20	11.6636	87.0192	100	100	NO	LG	4	Y	120	SZ	0	0	L	SZ
Olive ridley sea turtle	1	16-Dec	18:27	11.6709	87.0263	100	100	SA	SW	4	Y	121	SZ	0	0	L	SZ
Olive ridley sea turtle	1	16-Dec	18:52	11.6940	87.0489	20	107	NO	LG	4	Y	120	SZ	0	0	L	SZ
Olive ridley sea turtle	1	16-Dec	19:03	11.7040	87.0586	80	128	NO	LG	4	Y	119	SZ	0	0	L	SZ
Olive ridley sea turtle	1	16-Dec	19:27	11.7272	87.0813	60	142	SA	DI	4	Y	119	SZ	0	0	L	SZ
Unidentified sea turtle	1	16-Dec	21:50	11.8654	87.2156	200	150	SP	SW	4	Y	118	PD	1	45	L	PD
Olive ridley sea turtle	1	17-Dec	12:44	11.8671	87.285	30	98	NO	LG	5	Y	123	SZ	0	0	L	SZ
Unidentified sea turtle	1	17-Dec	14:07	11.9484	87.2052	105	108	SP	LG	5	Y	114	SZ	0	0	L	SZ
Unidentified sea turtle	1	17-Dec	14:16	11.9578	87.196	90	151	NO	LG	5	Y	114	SZ	0	0	L	SZ
Olive ridley sea turtle	1	17-Dec	14:22	11.9635	87.1904	110	123	NO	LG	5	Y	114	SZ	0	0	L	SZ
Unidentified sea turtle	1	17-Dec	15:21	12.0215	87.1334	120	117	NO	LG	4	Y	104	SZ	0	0	L	SZ
Olive ridley sea turtle	1	17-Dec	15:58	12.0575	87.0982	40	25	NO	DI	4	Y	94	SZ	0	0	L	SZ
Olive ridley sea turtle	1	17-Dec	16:44	12.1018	87.0546	200	200	SP	SW	2	Y	76	PD	1	45	L	PD
Unidentified sea turtle	1	17-Dec	17:06	12.1234	87.0335	3151	1201	NO	LG	2	Y	64	LS	3	135	L	
Unidentified sea turtle	1	17-Dec	17:22	12.1390	87.0182	450	450	NO	DE	3	N	54	LS	3	135	L	
Olive ridley sea turtle	1	17-Dec	18:51	12.0765	86.9758	10	10	SP	SW	3	Y	68	SZ	0	0	L	SZ
Olive ridley sea turtle	1	17-Dec	18:56	12.0719	86.9807	10	10	NO	LG	2	N	68	OT	0	0	L	
Olive ridley sea turtle	1	17-Dec	19:14	12.0559	86.9961	200	180	NO	LG	2	Y	75	OT	0	0	L	SZ
Olive ridley sea turtle	1	17-Dec	19:14	12.0559	86.9962	30	10	SP	SW	2	Y	76	OT	0	0	L	
Olive ridley sea turtle	1	17-Dec	19:23	12.0468	87.005	365	365	SA	SW	2	N	79	OT	0	0	L	
Unidentified sea turtle	1	17-Dec	19:29	12.0412	87.0106	993	993	UN	SW	2	N	80	OT	0	0	L	
Olive ridley sea turtle	1	17-Dec	19:32	12.0392	87.0126	40	30	SP	SW	2	N	81	OT	0	0	L	
Olive ridley sea turtle	1	17-Dec	20:07	12.0057	87.0454	90	80	NO	LG	2	N	93	SZ	0	0	L	SZ
Olive ridley sea turtle	1	17-Dec	20:09	12.0043	87.0467	40	30	UN	SW	2	N	93	OT	0	0	L	
Unidentified sea turtle	1	17-Dec	21:19	11.9395	87.1105	200	176	ST	SW	2	Y	109	PD	1	45	L	PD
Olive ridley sea turtle	1	20-Dec	16:56	8.8809	84.49	30	5	NO	RE	2	Y	2034	OT	0	0	L	
Olive ridley sea turtle	1	20-Dec	17:13	8.8513	84.4487	389	300	SP	SW	1	Y	1917	OT	0	0	L	
Olive ridley sea turtle	1	20-Dec	17:52	8.7841	84.3556	1125	80	NO	LG	1	Y	1663	OT	0	0	L	
Olive ridley sea turtle	1	20-Dec	18:30	8.7194	84.2626	450	60	NO	LG	1	Y	1261	OT	0	0	L	
Olive ridley sea turtle	1	20-Dec	19:14	8.6447	84.1566	600	55	NO	LG	1	Y	1118	OT	0	0	L	
Olive ridley sea turtle	1	20-Dec	22:21	8.3481	83.7251	1	1	NO	LG	3	Y	1231	OT	0	0	L	
Olive ridley sea turtle	1	20-Dec	22:42	8.3156	83.6789	75	5	ST	SW	3	Y	1875	OT	0	0	L	
Olive ridley sea turtle	1	21-Dec	19:17	7.0022	80.6463	50	50	NO	LG	3	Y	1903	OT	0	0	L	

[a] CPA is the distance at the closest observed point of approach to the nearest airgun. This is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel.

[b] The initial movement of the individual or group relative to the vessel. UN=unknown, NO=no movement, SA=swimming away, SP=swimming parallel, ST=swimming toward.

[c] The initial behavior observed. DE=dead, DI=diving, SW=swimming, RE=resting, LG=logging, MA=mating.

[d] Beaufort Wind Force scale (which is not the same as the "Sea State" scale).

[e] See *Acronyms and Abbreviations* and Chapter 3 *Analyses* for definition of "useable".

[f] Water depth was recorded for the vessel's location when a sighting was made.

[g] Activity of the vessel at the time of the sighting. SH= operating airguns offline usually during turns between seismic lines, LS=operating airguns on a seismic survey line and collecting geophysical data, PD=power down of airguns, RU=ramp up, SZ=shut down for turtle in safety zone, OT=other (a period of no seismic activity either during transit or a period after an SZ); None=blank.

APPENDIX I.2. Sea turtle sightings that prompted power downs or shut downs of the GI guns during the ETPCA seismic cruise, 21 Nov. – 22 Dec. 2004.

Species	Group size	Date (2004)	Water depth (m)	Initial sighting distance[1] (m)	Movement[2]	Dove? (yes/no)	Number & size (in^3) of GI guns on[3]	Total GI gun volume (in^3)[4]	CPA (m) to operating GI guns	Mitigation measure taken (PD or SZ)
Unidentified sea turtle	2	23-Nov	79	200	NO	Y	3 x 45	135	60	SZ
Unidentified sea turtle	1	23-Nov	87	15	NO	N	1 x 45	45	10	SZ
Unidentified sea turtle	1	23-Nov	78	20	NO	Y	2 x 45	90	20	SZ
Unidentified sea turtle	1	25-Nov	103	277	NO	N	3 x 45	135	270	PD
Unidentified sea turtle	1	25-Nov	93	928	NO	N	3 x 45	135	736	SZ
Unidentified sea turtle	1	25-Nov	90	1017	NO	N	88	99	650	SZ
Leatherback sea turtle	1	25-Nov	69	10	ST	Y	2 x 45	90	0	SZ
Olive Ridley's sea turtle	1	25-Nov	91	5	ST	Y	3 x 45	135	0	SZ
Unidentified sea turtle	2	25-Nov	119	200	NO	N	3 x 45	135	30	SZ
Olive Ridley's sea turtle	1	26-Nov	114	40	NO	N	3 x 45	135	40	SZ
Olive Ridley's sea turtle	1	26-Nov	117	20	NO	N	3 x 45	135	5	SZ
Olive Ridley's sea turtle	1	27-Nov	89	150	NO	Y	3 x 45	135	100	SZ
Olive Ridley's sea turtle	2	27-Nov	91	150	NO	N	3 x 45	135	35	SZ
Unidentified sea turtle	1	27-Nov	87	854	NO	N	88	99	650	SZ
Unidentified sea turtle	1	27-Nov	100	200	NO	N	3 x 45	135	200	SZ
Unidentified sea turtle	1	27-Nov	102	389	NO	N	3 x 45	135	277	PD
Olive Ridley's sea turtle	1	27-Nov	103	20	NO	N	1 x 45	45	10	SZ
Olive Ridley's sea turtle	2	27-Nov	102	300	NO	N	3 x 45	135	40	SZ
Unidentified sea turtle	2	27-Nov	101	533	NO	N	3 x 45	135	150	PD
Unidentified sea turtle	1	28-Nov	108	60	NO	N	3 x 45	135	20	SZ
Unidentified sea turtle	1	30-Nov	128	389	NO	N	3 x 45	135	350	PD
Unidentified sea turtle	1	1-Dec	1049	5	ST	N	3 x 45	135	5	SZ
Unidentified sea turtle	1	2-Dec	134	5	NO	N	3 x 45	135	5	SZ
Unidentified sea turtle	1	4-Dec	676	175	SA	N	3 x 105	315	125	SZ
Unidentified sea turtle	1	4-Dec	536	130	NO	Y	3 x 105	315	90	SZ
Olive Ridley's sea turtle	1	4-Dec	396	85	NO	Y	3 x 105	315	20	SZ
Unidentified sea turtle	1	4-Dec	224	200	NO	Y	3 x 105	315	150	PD
Olive Ridley's sea turtle	1	4-Dec	158	5	NO	N	3 x 105	315	5	SZ

Species	Group size	Date (2004)	Water depth (m)	Initial sighting distance[1] (m)	Movement[2]	Dove? (yes/no)	Number & size (in^3) of GI guns on[3]	Total GI gun volume (in^3)[4]	CPA (m) to operating GI guns	Mitigation measure taken (PD or SZ)
Unidentified sea turtle	1	5-Dec	967	50	NO	N	3 x 45	135	5	SZ
Unidentified sea turtle	1	5-Dec	907	10	SA	Y	3 x 45	135	10	SZ
Olive Ridley's sea turtle	1	5-Dec	422	135	SA	Y	3 x 45	135	135	PD
Unidentified sea turtle	1	5-Dec	395	20	SP	Y	3 x 45	135	20	SZ
Olive Ridley's sea turtle	1	6-Dec	128	30	NO	Y	3 x 45	135	15	SZ
Olive Ridley's sea turtle	1	6-Dec	116	45	NO	Y	3 x 45	135	20	SZ
Olive Ridley's sea turtle	1	6-Dec	274	30	NO	Y	3 x 45	135	10	SZ
Unidentified sea turtle	1	6-Dec	420	200	NO	Y	3 x 45	135	75	SZ
Olive Ridley's sea turtle	1	6-Dec	746	25	NO	N	3 x 45	135	5	SZ
Olive Ridley's sea turtle	1	6-Dec	780	225	NO	N	3 x 45	135	200	PD
Olive Ridley's sea turtle	1	6-Dec	1034	200	NO	N	3 x 45	135	200	PD
Olive Ridley's sea turtle	1	6-Dec	1176	180	NO	Y	3 x 45	135	150	PD
Olive Ridley's sea turtle	1	7-Dec	111	100	NO	Y	3 x 45	135	90	SZ
Olive Ridley's sea turtle	1	7-Dec	113	50	NO	N	3 x 45	135	30	SZ
Olive Ridley's sea turtle	1	7-Dec	113	30	NO	Y	3 x 45	135	30	SZ
Unidentified sea turtle	1	7-Dec	114	100	SP	Y	3 x 45	135	100	SZ
Olive Ridley's sea turtle	1	7-Dec	115	60	SP	Y	3 x 45	135	30	SZ
Unidentified sea turtle	1	7-Dec	125	15	SP	Y	3 x 45	135	10	SZ
Olive Ridley's sea turtle	1	8-Dec	169	10	NO	Y	3 x 45	135	10	SZ
Olive Ridley's sea turtle	1	8-Dec	157	5	NO	N	3 x 45	135	5	SZ
Olive Ridley's sea turtle	1	8-Dec	142	85	SP	Y	3 x 45	135	35	SZ
Olive Ridley's sea turtle	1	8-Dec	138	130	NO	N	3 x 45	135	90	SZ
Olive Ridley's sea turtle	1	8-Dec	128	277	NO	Y	3 x 45	135	200	PD
Olive Ridley's sea turtle	1	8-Dec	127	100	NO	Y	3 x 45	135	50	SZ
Olive Ridley's sea turtle	1	8-Dec	123	200	NO	Y	3 x 45	135	30	SZ
Olive Ridley's sea turtle	1	8-Dec	121	50	NO	Y	3 x 45	135	10	SZ
Olive Ridley's sea turtle	1	8-Dec	120	200	NO	N	3 x 45	135	90	SZ
Unidentified sea turtle	1	10-Dec	129	80	NO	Y	3 x 45	135	45	SZ
Unidentified sea turtle	1	10-Dec	131	105	NO	N	3 x 45	135	105	SZ
Olive Ridley's sea turtle	1	10-Dec	134	70	NO	Y	3 x 45	135	55	SZ
Olive Ridley's sea turtle	1	10-Dec	134	200	NO	Y	3 x 45	135	200	PD
Olive Ridley's sea turtle	1	10-Dec	134	30	NO	Y	3 x 45	135	20	SZ
Olive Ridley's sea turtle	1	10-Dec	131	100	SP	Y	3 x 45	135	50	SZ

Species	Group size	Date (2004)	Water depth (m)	Initial sighting distance[1] (m)	Movement[2]	Dove? (yes/no)	Number & size (in^3) of GI guns on[3]	Total GI gun volume (in^3)[4]	CPA (m) to operating GI guns	Mitigation measure taken (PD or SZ)
Olive Ridley's sea turtle	1	10-Dec	131	100	SP	Y	3 x 45	135	50	SZ
Olive Ridley's sea turtle	1	10-Dec	130	50	NO	Y	3 x 45	135	30	SZ
Olive Ridley's sea turtle	1	10-Dec	130	232	NO	Y	3 x 45	135	200	PD
Olive Ridley's sea turtle	1	14-Dec	113	40	NO	Y	3 x 45	135	0	SZ
Olive Ridley's sea turtle	1	14-Dec	69	120	NO	Y	1 x 45	45	80	SZ
Unidentified sea turtle	1	16-Dec	150	10	NO	Y	3 x 45	135	10	SZ
Olive Ridley's sea turtle	1	16-Dec	128	110	NO	Y	3 x 45	135	40	SZ
Olive Ridley's sea turtle	1	16-Dec	121	120	SP	N	3 x 45	135	80	SZ
Olive Ridley's sea turtle	1	16-Dec	121	120	NO	Y	3 x 45	135	100	SZ
Olive Ridley's sea turtle	1	16-Dec	120	250	SA	N	3 x 45	135	250	PD
Olive Ridley's sea turtle	1	16-Dec	120	100	NO	Y	3 x 45	135	100	SZ
Olive Ridley's sea turtle	1	16-Dec	121	100	SA	N	3 x 45	135	100	SZ
Olive Ridley's sea turtle	1	16-Dec	120	20	NO	Y	3 x 45	135	20	SZ
Olive Ridley's sea turtle	1	16-Dec	119	80	NO	N	3 x 45	135	60	SZ
Olive Ridley's sea turtle	1	16-Dec	119	60	SA	Y	3 x 45	135	60	SZ
Unidentified sea turtle	1	16-Dec	118	200	SP	N	3 x 45	135	150	PD
Olive Ridley's sea turtle	1	17-Dec	123	30	NO	Y	3 x 45	135	20	SZ
Unidentified sea turtle	1	17-Dec	114	105	SP	N	3 x 45	135	35	SZ
Unidentified sea turtle	1	17-Dec	114	90	NO	Y	3 x 45	135	70	SZ
Olive Ridley's sea turtle	1	17-Dec	114	110	NO	N	3 x 45	135	40	SZ
Unidentified sea turtle	1	17-Dec	104	120	NO	Y	3 x 45	135	30	SZ
Olive Ridley's sea turtle	1	17-Dec	94	40	NO	Y	3 x 45	135	25	SZ
Olive Ridley's sea turtle	1	17-Dec	76	200	SP	N	3 x 45	135	200	PD
Olive Ridley's sea turtle	1	17-Dec	68	10	SP	Y	3 x 45	135	10	SZ
Olive Ridley's sea turtle	1	17-Dec	75	200	NO	Y	1 x 45	45	180	SZ
Olive Ridley's sea turtle	1	17-Dec	93	90	NO	N	3 x 45	135	80	SZ
Unidentified sea turtle	1	17-Dec	109	200	ST	Y	3 x 45	135	176	PD

[1] "Initial Sighting Distance" is the first recorded distance from the observation station to the animal; "CPA" is the closest observed point of approach to operating GI gun(s).

[2] Initial movement of group relative to the vessel: ST = swim toward, SP = swim parallel, SA = swim away, NO = no movement.

[3] 88 indicates ramp up, or undetermined number of GI guns operating.

[4] 99 indicates ramp up, or undetermined GI gun volume.

APPENDIX I.3. Number of sea turtle groups observed over various water depth ranges during the ETPCA cruise, 21 Nov. – 22 Dec. 2005. Only "useable"[a] data are included.

	Water depth (m) - Seismic				Water depth (m) - Non-seismic				
Species	**< 100 m**	**100 - 1000 m**	**> 1000 m**	**Sub-Total**	**< 100 m**	**100 - 1000 m**	**> 1000 m**	**Sub-Total**	**GRAND TOTAL**
Green sea turtle	-	-	-	-	1	-	-	1	1
Leatherback	1	-	-	1	-	-	-	-	1
Olive ridley sea turtle	9	44	2	58	-	1	8	9	67
Unidentified turtles	8	37	2	49	2	3	-	5	54
Total	18	81	4	108	3	4	8	15	123

[a] Useable detections are those made during useable daylight visual observations as defined in *Acronyms and Abbreviations* and in Chapter 3 *Analyses*. This excludes a total of 43 turtle sightings that occurred during the "post-seismic" period and 5 sightings of dead sea turtles.